

AERO DIGEST

AVIATION ENGINEERING

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AUGUST 1956
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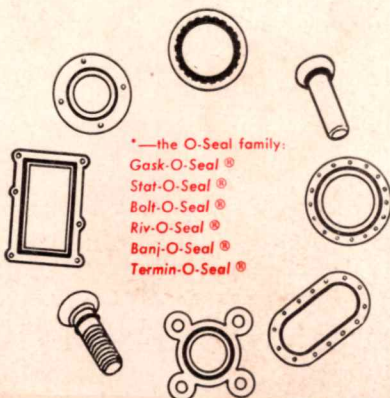
THIS ISSUE
EMPLOYMENT SURVEY
GAS TURBINE MATERIALS
ON-OFF STABILIZATION SYSTEMS



This Little "Gadget" Went to Market!

Not quite ten years ago the Franklin C. Wolfe Company started manufacturing the Lock-O-Seal[®] shown above. It marked the beginning of a new conception for **no-leakage static sealing.**

Today there is a whole family of "O-Seals"*—to seal flanges, fittings, and fasteners for a broad range of temperatures, pressures and materials. Why not find out about these seals for your projects? We maintain a free design service to help solve static sealing problems **at the design stage.**



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FRANKLIN C. WOLFE CO.

"sealing design specialist"

Culver City, California



Rascal

longer "reach"
for the
Air Force

Guided missiles, a fantasy yesterday, are a working reality today. One of the most important concepts in this field is the GAM-63 Rascal, a USAF air-to-surface missile for which Bell Aircraft Corp. has the weapon system responsibility.

Rascal is designed to be carried aloft by USAF strategic bombers and released miles from its objective. Even while the bomber is on the return flight to its home base, Rascal is heading at a high speed and with pin-point accuracy to its target.

The rocket-powered Rascal not only can increase the "reach" of the Air Force but also could eliminate the hazardous "run over the target" for airmen and extend the useful life of the nation's bombardment aircraft.

As the prime contractor, Bell Aircraft has been associated with a large segment of U. S. Industry in developing the entire Rascal weapon system. This system includes the airframe, guidance, rocket engine, servomechanical devices, launching and ground support equipment, flight testing and training.

The Air Force-Industry team urgently needs scientists and engineers for projects vital to the nation's defense. Opportunities to make important contributions are offered in military or civilian careers.

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BUFFALO, N. Y.

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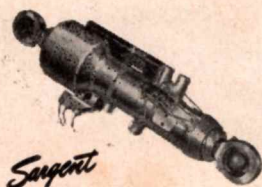
WIG-O-FLEX Coupling

INST-O-MATIC Coupling

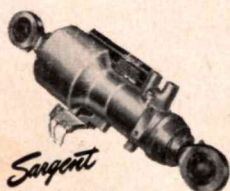
CONNECT-O-MATIC Coupling

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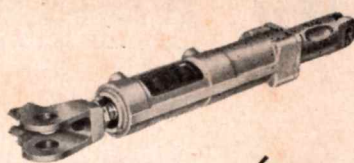
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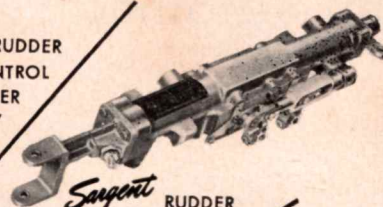
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2 INBOARD
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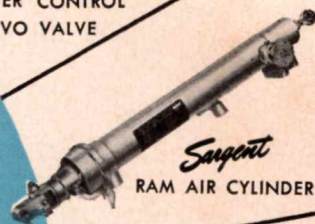
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2 OUTBOARD
DROOP CYLINDERS



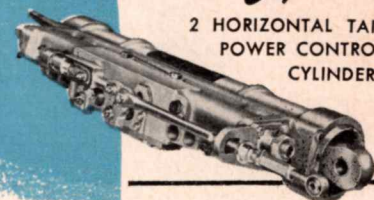
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Sargent
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CYLINDERS

World's Fastest Navy Fighter

9 Proudly wears
Sargent controls

Nine Sargent quality units have been selected to provide Chance Vought's F8U-1 Crusader with instantaneous, positive, feathertouch response.

These units, Sargent fabricated to Vought specifications, provide a system for control for the safe, positive, efficient operation of this great fighter.

The experience of more than 36 years of design and manufacture of precision equipment systems has given Sargent Engineering Corporation the "know-how" to aid in solving the essential and advance problems of force control. Leading airframe and missile manufacturers are using hundreds of different Sargent hydraulic, mechanical, pneumatic, electrical and electronic force control units on the nation's military planes, commercial planes and missiles.

Sargent places its facilities of design and manufacture at your disposal. We invite you to send your specifications for the Sargent proposal of your force control problems.

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"GOOD WILL" is the disposition of the pleased customer to return to the place where he has been well treated.

—U. S. Supreme Court



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BUILDS QUALITY THAT BUILDS GOOD WILL

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AERO DIGEST

AERO DIGEST

AVIATION ENGINEERING

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Advertising Representatives

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Alfred S. Reed
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DETROIT

W. E. Fellows—Harry C. Brewster
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Phone Trinity 5-8216

LOS ANGELES

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CHICAGO

Kenneth A. Kruse
53 West Jackson St.
Phone Webster 9-5634

CANADA

Allin Associates
Suite 220
1220 Richmond St., E.
Toronto, Ontario, Canada

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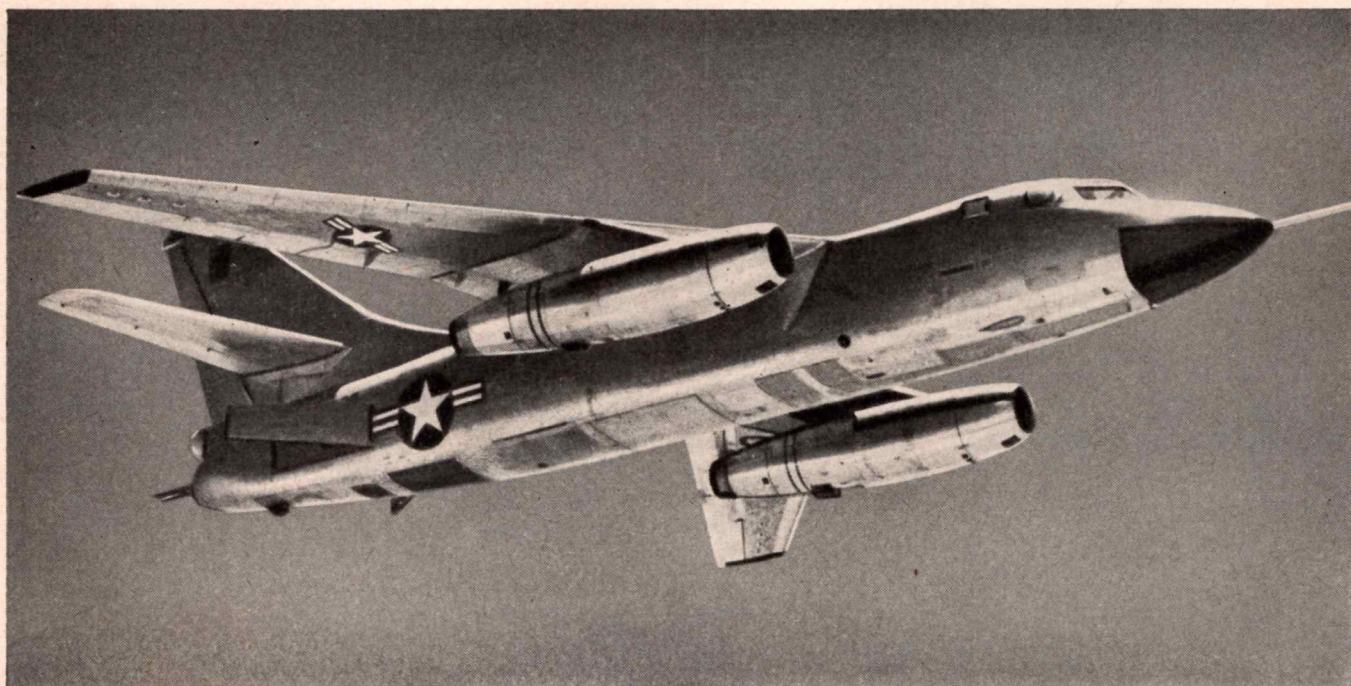
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"EYES"

**FOR THE AIR FORCE
TACTICAL AIR COMMAND**



Air Force RB-66 powered by Allison J71 Turbo-Jet Engines



ALLISON

**TURBO-JET
AND TURBO-PROP POWER**



Here you see the Tactical Air Command's newest reconnaissance bomber—the all-weather twin-jet Douglas RB-66.

It carries a payload of nuclear or conventional bombs—which it can wing at 600-700 mph to targets dictated by the nation's needs.

It packs a full complement of camera equipment—which also makes it a valuable reconnaissance tool for air intelligence.

And in pods under its wings it boasts a pair of Allison J71 Turbo-Jet engines — each producing 10,000 pounds' thrust without augmentation — which take it to altitudes over 40,000 feet.

Now winning its wings for reliability and dependability with the 363rd Tactical Reconnaissance Wing at Shaw Air Force Base, S. C., the Allison-powered RB-66 carries a three-man crew as it goes on its peace-maintaining missions.

The Allison-powered Douglas RB-66 is another example of how continuous engine development —both Turbo-Jet and Turbo-Prop—is helping keep America first in the air.

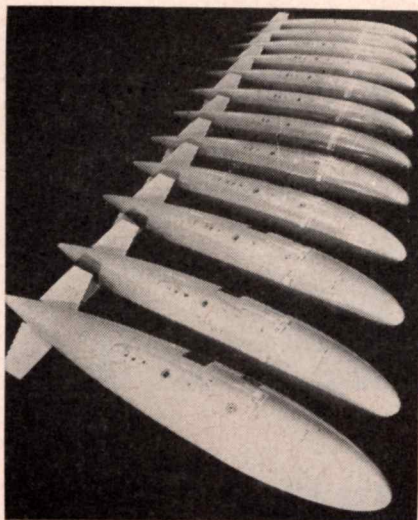
ALLISON DIVISION OF GENERAL MOTORS, Indianapolis, Indiana

AMERICAN BUILT FOR THE JET ERA IN AIR TRAVEL

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aero news digest

News In Brief

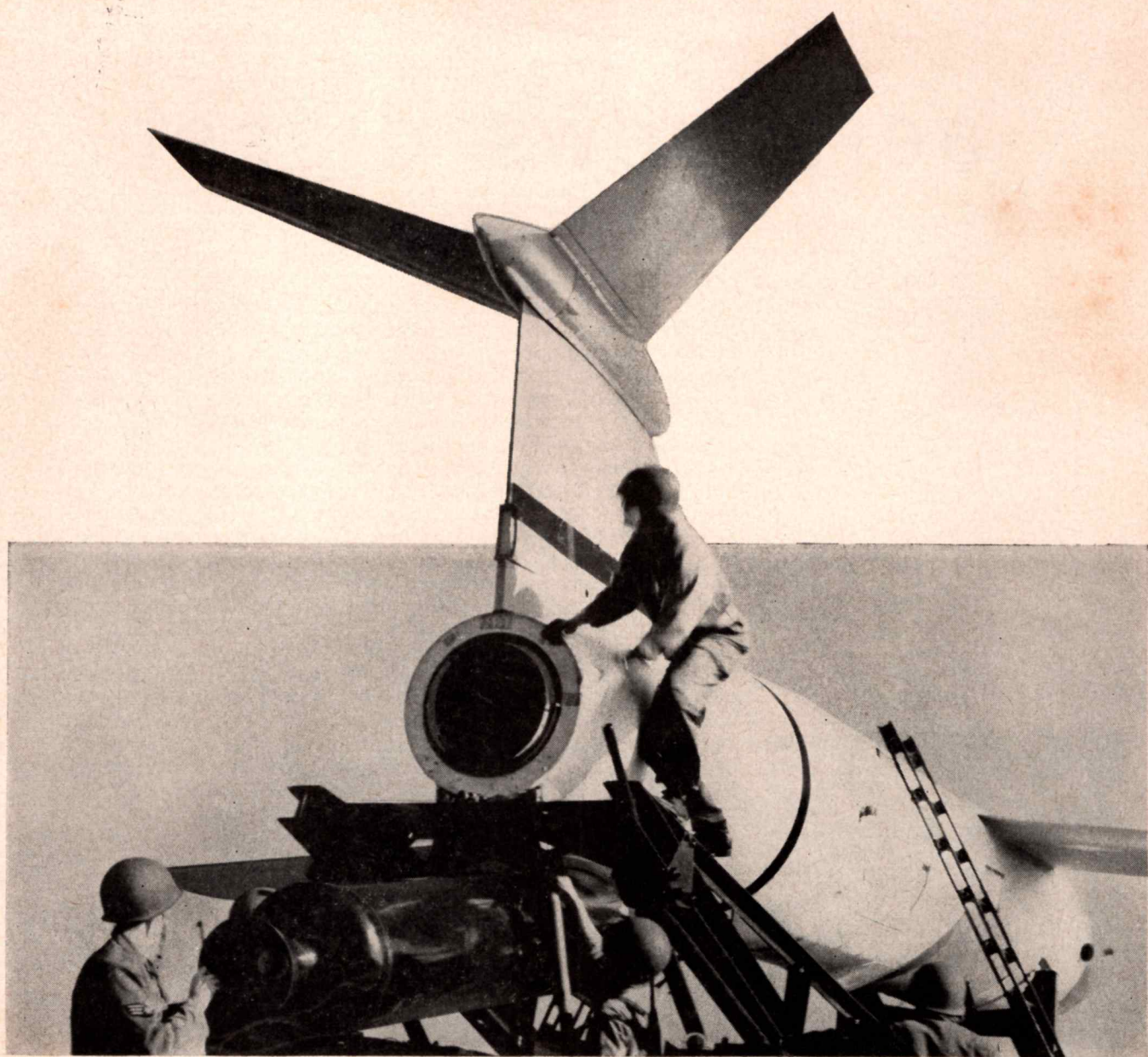


100-gallon plastic drop tanks developed by Bristol Aircraft Ltd.

Signs of the times are seen in Convair's recently announced Astronautics Division, a \$40-million facility in San Diego, scheduled for completion in 1957. The Atlas intercontinental ballistic missile will be built at this plant, which is to be devoted to research, development and preliminary testing of the Atlas as well as to "related projects looking into the future of astronautics" . . . Contractor for the electronic flight control system for the Douglas DC-8 is Sperry Gyroscope. Called the SP-30, the first prototype system is due at Douglas this fall. Production systems are promised for next June . . . British firms Avro and Saunders-Roe reveal that they are building mixed powerplant fighters, the 720 and the S.R. 53. Although the make and type engines to be used are secret, they are believed to be the turbojet-rocket combination . . . Intensive study of turbojet inlet diffuser control is being started by the Aeronautical Division of Minneapolis-Honeywell Regulator Company under a \$250,000 contract awarded by Wright Air Development Command . . . Going under the military designation TT-1, Temco Aircraft's Model 51, a sleek two-place jet-powered aircraft, will be the Navy's first primary jet trainer. Delivery of the first aircraft is scheduled for July 1957. According to a company spokesman, an "increase in the number of employees to handle production (of the TT-1) is expected to be appreciable." . . . The "Jet Stream" is again being pursued by a team of Air Force scientists, technicians and pilots. Past tests have been run using aircraft based in Florida. For this new venture, the base of operations is at Wright-Patterson AFB, Ohio, since during summer months the stream frequently moves over northern United States and southern Canada . . . The Air Force Operational Test Center, Eglin AFB, Florida, has started testing the Boeing KB-50 aerial tanker. The KB-50, a modification of the post World War II Superfortress, is capable of refueling three planes simultaneously, thereby greatly extending the combat range of jet fighters and light bombers . . . Aerojet-General's Aerobee-Hi rocket, which recently rose to a world's altitude record of 163 miles, is being fitted with a ceramic thrust chamber. The next few months will see this new development being tested . . . A star group of Princeton professors have jumped on the consulting engineering band wagon by forming a company to do research and development work in the missile and jet propulsion fields. Called Aerokinetics, Inc., the organization has on its outside-of-university-hours staff Dr. Luigi Crocco, Dr. Martin Summerfield, Dr. John B. Fenn, Dr. Sin-I Cheng, Mr. J. Preston Layton, Dr. Irvin Glassman and Dr. Jerry Grey . . .

"Sea Bat" Described—Somewhat

The Navy Department has revealed that Piasecki Aircraft Corporation is building under contract an "experimental vertical lift aeronautical development" nick-named the "Sea Bat." Frank N. Piasecki, president of



"FOR IMMEDIATE RELEASE"

"Six boxes and a handbook."

Those were the materials that have proved out one of the big engineering achievements of our time. It concerns a whole new concept of *customer service* developed to provide optimum efficiency in the delivery and performance of weapon systems.

The TM-61 Martin Matador shown here at an overseas Air Force base arrived there in six packing cases, and was stockpiled in a storage depot.

When the test-drill whistle blew, a team of Air Force technicians assembled and checked out the missile, complete with mobile guidance system, and ready for firing, in less than six hours.

Martin engineering service today covers every aspect of the customer's requirements for effective operation and maintenance of the product. This includes packaging, delivery, customer training, field service and contractor maintenance.

MARTIN

For further information circle Reader Reply No. 30

AERO DIGEST

the company, says that the "Sea Bat" will be unmanned and completely automatic in flight and controlled electronically from shipboard or land bases. "Its compactness permits its operation from restricted areas aboard small warships, and it can be stowed aboard submarines. It can perform a multitude of missions that cannot now be done by existing aircraft or helicopters." Throughout its flight, including vertical take-off, it retains its horizontal attitude as does the conventional airplane. When asked the nature of the aircraft the Navy had "no comment".

How to Handle Engineers

To answer questions asked about the care and feeding of engineer employees and their employers, the National Society of Professional Engineers in Washington, D. C., is releasing a report called, "Criteria for Professional Employment of Engineers." The report comprises a check list by which engineers and their employers may gauge their success in dealing with each other. The basic concepts used in preparing the report are stated to be: (1) The only satisfactory method of dealing with engineer-employer relationships is on a cooperative common-interest status. (2) The engineer shares an equal responsibility with the employer in elevating his professional status. (3) Management should regard the engineer as one who is identified with the management team, whether the engineer is in a supervisory or non-supervisory position. (4) The engineer must be company-minded and think in terms of the company's problems and growth, as well as his own.

Japan Builds Jet Aircraft

The first Japanese-designed and manufactured jet aircraft will be rolled out in about a year. Responsible for production of the intermediate jet trainer is Fuji Heavy Industries, Ltd. Called the F1F1, the aircraft design calls for a wing span of 34.5 feet; wing area, 237 square feet; fuselage length, 39.5 feet; and a gross weight of 7300 pounds. Powered by a Bristol Orpheus turbojet, the aircraft's design maximum speed is pegged at 500 mph. The powerplant will be replaced later by a Japanese-designed turbojet (J3-1) now being developed by the Japan Jet Engine Company.

ONR Marks Tenth Anniversary

Ten years ago this month the Office of Naval Research started in business. Since that beginning, it has served as a meeting place and clearing house for engineers and scientists able to give us a better Navy. ONR's contributions to aviation include development of the Flying Platform, the Aerodyne, VTO and STOL aircraft, and the application of boundary layer control. Delving into basic theory to bolster practical work, ONR has backed research in fields such as the metallurgy of titanium, fuel chemistry, jet and nuclear propulsion, and computer engineering. In addition to conducting its own projects, ONR coordinates the research program for the entire Navy and administers the Navy's patent program.

Jet Wake Studied

The Air Force has asked Armour Research Foundation of Illinois Institute of Technology, Chicago, to develop a method to suppress the visibility of vapor track from a jet's wake. The "contrails" will be simulated in the laboratory through the use of a steam generator. Photo-electric equipment will record the amount of light

DOUBLE WASPS MEAN FOR NEW CONVAIR



**Convair 440s already have
been ordered by:**

BRANIFF INTERNATIONAL AIRWAYS
CONTINENTAL AIR LINES
DELTA AIR LINES
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AERO O/Y (*Finland*)
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IBERIA (*Spain*)
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SABENA BELGIAN WORLD AIRLINES
SCANDINAVIAN AIRLINES SYSTEM
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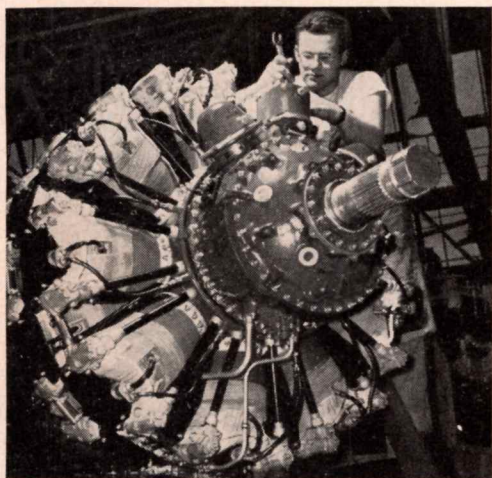
TOP PERFORMANCE METROPOLITAN 440

THE METROPOLITAN 440, latest in the famed series of Convair-Liners, is being welcomed into service this year by many leading airlines around the world.

One of the most efficient airliners in its class, with a payload of up to 52 passengers, and a cruising speed near 300 mph, the *Metropolitan* offers new luxury and a quieter passenger cabin with greatly increased soundproofing. Like all Convair-Liners in airline service, the *Metropolitan* is powered by Pratt &

Whitney Aircraft Double Wasp engines.

The R-2800 Double Wasp currently powers nine types of commercial transports flown by 72 airlines throughout the world, and a wide range of Air Force and Navy aircraft as well. This engine has established an outstanding record of power, dependability, and economy in well over a thousand airliners—a record that will assure top performance for Convair's new *Metropolitan*.



The 18-cylinder Double Wasp engine powers well over 1000 of the free world's modern airliners... including the Convair 240, 340 and 440; the Douglas DC-6, DC-6A and DC-6B; the Martin 2-0-2 and 4-0-4; and the Breguet 763. The latest Double Wasp develops 2500 horsepower for takeoff.

PRATT & WHITNEY AIRCRAFT

Division of United Aircraft Corporation • Main Office and Plant: East Hartford, Connecticut
Branch Plants: North Haven—Southington—Meriden

reflected from the trail. A study will also be made of the amounts of light given off by the various chemicals in the vapor trail. The vapor track can be caused by any aircraft, but is most common with jets, probably because of the higher altitude flown and the colder temperatures encountered. Vapor trails are caused when meteorological circumstances are right, and usually only when the higher layer of air has a temperature colder than -45°F .

High-Temperature Commutator Alloy

A copper-zirconium alloy possessing high electrical conductivity and good strength-retention at elevated temperatures has been developed by technologists at Battelle Institute, Columbus, Ohio. It is suitable for electric motor commutators serving at temperatures above 500°F , and under conditions where strength is required. This alloy is the result of research for the Nippert Electric Products Company of Columbus, Ohio. Electrical conductivity of the alloy is 95.8 percent of that of the copper standard. Rate of loss of strength under load is exceptionally low by commutator alloy standards.

Supersonic Propeller Proposed

The ramprop, a jet-driven propeller turning with supersonic speeds, could give vertical takeoff and landing aircraft the load-carrying capacity and speed of modern transport aircraft, Albert Gail, Aerodynamics Research Engineer at Cornell Aeronautical Laboratory, Inc., reports. The ramprop is a propulsion system consisting of rotor blades driven at supersonic speed by ramjets or ramrockets at the blade tips. "Even under very pessimistic assumptions, the ramprop promises to out-perform its potential rivals, the turbojet, the turbofan and turboprop, as a powerplant for vertically rising and descending aircraft capable of high-speed level flights," Gail says.

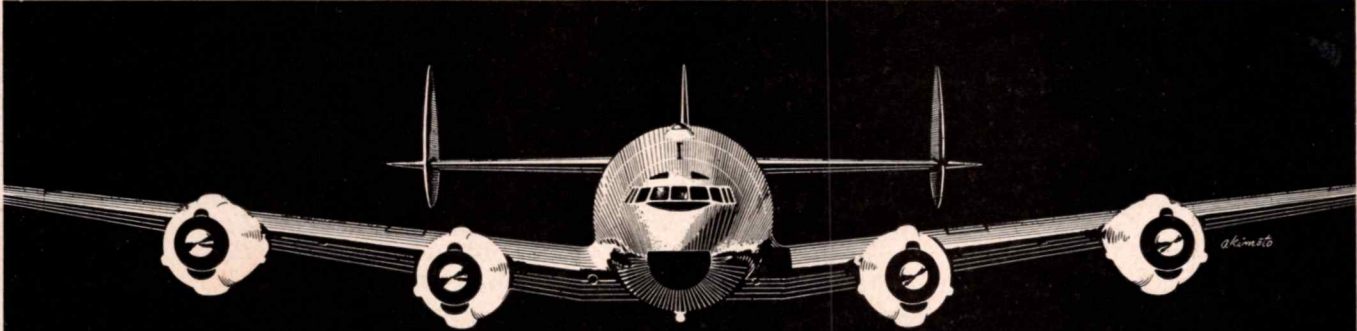
Missile Test-Range Instrumented

The world's longest missile test range will soon be wired for sound. The Air Research and Development Command has let a \$1.2-million contract to the Consolidated Electrodynamics Corporation of Pasadena, California, to provide magnetic-tape instrumentation along the 5000 mile test range. ARDC's test range stretches south-eastwardly from the launch site outside the Missile Test Center, Patrick AFB, Florida, across the Atlantic to Ascension Island off the African coast. It is here that the Air Force plans to test its intercontinental ballistic missiles. The magnetic-tape equipment, placed at over 100 strategic points on the ground and aboard ships along the 5000 mile range, will record telemetered data from the missiles, such as temperature, pressure and thrust, and play it back for analysis and interpretation.

New Environmental Test Chamber

Weather conditions ranging from the subfreezing cold of Siberia to steaming African jungles will be simulated in a testing chamber just completed at the

Pictured below are four reasons why Rohr is world-famous as the builder of ready-to-install Pow-R-Pax for airplanes. In addition to the Lockheed Super G Constellation—Rohr builds the Pow-R-Pax for many other leading commercial and military planes including the Boeing KC-135, B-52, Douglas DC-7 and the Convair 440.

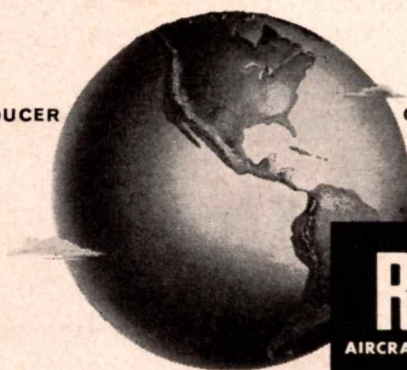


POW-R-PAX
on the wing
OF THE LOCKHEED SUPER G CONSTELLATION

PLUS OVER 30,000 OTHER DIFFERENT AIRCRAFT PARTS. Currently, Rohr is producing over 30,000 different parts for aircraft of all kinds—utilizing the vast design, engineering and production experience gained from building thousands upon thousands of power packages...far more than anyone else in the world..

WORLD'S LARGEST PRODUCER

OF READY-TO-INSTALL POW-R-PAX FOR AIRPLANES



ROHR

AIRCRAFT CORPORATION

Chula Vista and Riverside, California

Westinghouse Electric Corporation Air Arm Division plant in Baltimore. One of the most advanced chambers of its kind, the \$275,000 facility will be used by the electrical test department to evaluate the effect of various weather conditions on airborne electronic systems being built for the Navy and the Air Force.

Orenda Turbojet Under Test

Under development by Orenda Engines Limited, the Iroquois turbojet, formerly known as the PS-13, has successfully passed its 50-hour preliminary flight rating test. The engine is to power the RCAF's first supersonic interceptor, the CF-105.

Do They Mean "Big Brother"?

Republic Aviation Corporation plans to double its Guided Missiles Division's facilities for research, development and production. The division, which has been doing top secret work on two new guided missile systems, at present has a staff of about 120 engineers and 30 shop mechanics which it intends to augment as soon as new, air-conditioned quarters are available, sometime this summer. Though the division has been little publicized, officials said it is working on a missile "that can be considered more advanced than the much-discussed earth satellite" that will be launched into outer space next year. They may have the "Big Brother" reconnaissance satellite in mind.

Names In The News

Arthur D. Little, Inc. elected WILLIAM A. W. KREBS, JR. and DR. HOWARD O. McMAHON to vice president posts . . . New president of Chatham Electronics Division of Gera Corporation is ANTHONY SCALA . . . HUGH F. COLVIN named president of Consolidated Electrodynamics Corporation . . . Ethyl Corporation announces election of EDWARD L. SHEA to chairman of the board and of B. BYNUM TURNER as president . . . WILLIAM C. MCFADDEN appointed executive vice president of Hycon Mfg. Company . . . CHARLES A. SERENO newly elected executive vice president of Air Associates, Incorporated . . . George A. Crowther named chief engineer of Ford Instrument Company, Division of Sperry Rand Corporation . . . Election of J. W. KEENER and ARTHUR KELLY as executive vice presidents announced by The B. F. Goodrich Company . . . Newly-created position of vice president in charge of engineering for Minneapolis-Honeywell Regulator Company filled by GLENN E. SEIDEL . . . IRA J. KARR elected vice president and engineering director for Hoffman Electronic Corporation.

COMING IN OCTOBER . . .

AERO DIGEST Procurement Issue

Read about:

Complete procedures for selling to the Army . . .

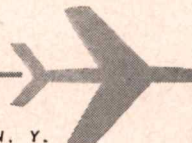
A new scientific theory that may revolutionize the Navy's buying requirements.



Did you ever notice that some of Nature's most amiable creatures are those most effectively equipped to deal sorrow to bullies? Now, we at REPUBLIC don't necessarily go all the way with the late Ernest Thompson Seton, who once said the much misunderstood skunk ought to be some sort of national symbol because of its peaceable disposition backed by formidable fire-power. But we do think history has shown that in human affairs, too, those who would live without fear must first earn respect.



REPUBLIC AVIATION



FARMINGDALE, LONG ISLAND, N. Y.

Designers and Builders of the Incomparable **THUNDER-CRAFT**

AUGUST 1956

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Power for the World's Airlines



AMERICAN, BRITISH,
DUTCH and FRENCH

built airliners,

powered by

ROLLS-ROYCE

GAS TURBINES,

have been ordered

by airlines of the world.



*Rolls-Royce gas turbines have already flown 1,000,000 hours
on scheduled airline service*

ROLLS-ROYCE AERO ENGINES LEAD THE WORLD

For further information circle Reader Reply No. 40

This "Big Stick" stops trouble

before it starts

So powerful that it revises infantry strategy, the Douglas *Honest John* is an artillery rocket of tremendous destructive force and deadly accuracy.

Designed and built by Douglas Aircraft, *Honest John* moves into position on its own launching truck. This free-flight missile can carry the heaviest high explosive charge, or an atomic warhead in weather that grounds tactical air cover. Its very existence deters an enemy from massing for effective ground attack.



**HONEST JOHN puts a mobile atomic
weapon up front with the infantry**

Development of *Honest John* by Douglas engineers fills a vital infantry need and provides new muscle for our armed forces. But the basic strength of any defense depends on the people manning it. Find out what an important future there is for *you* in U. S. Army service.

Depend on **DOUGLAS**



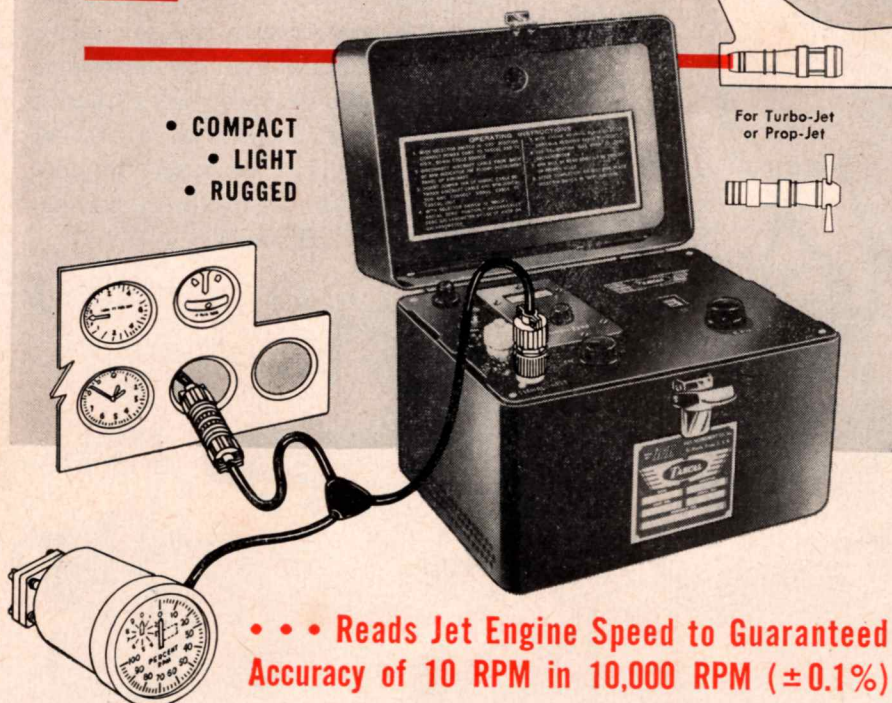
First in Aviation

Is your Jet Engine RPM Measurement Accurate???

The NEW B&H Instrument

TAKCAL

- COMPACT
- LIGHT
- RUGGED



• • • Reads Jet Engine Speed to Guaranteed Accuracy of 10 RPM in 10,000 RPM ($\pm 0.1\%$)

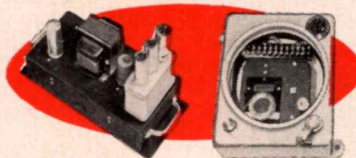
The inter-relation of RPM to efficiency and thrust in jet engines is fundamental. Proper adjustments for maximum thrust, engine life and safety of operation can be made only upon accuracy of instrumentation.

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new books

MOLECULAR FLOW OF GASES, G. N. Patterson, 1956, John Wiley & Sons, Ltd., New York. 217 pp, \$7.50.

Recent developments in supersonic aerodynamics have emphasized the importance of a molecular approach to the subject of gas dynamics. When only the macroscopic part of the motion of a gas is largely significant, the contribution made by the unseen internal motions of the molecules can be adequately taken into account by a phenomenological (or continuum) analysis. However, when the characteristics of a flow depend more essentially on the random motion of the molecules, as in the slip flow of a highly rarefied gas, or on the internal structure of the molecules, as indicated by the relaxation effects associated with a strong shock wave, then a theory of gas flow must be developed in which more attention is given to the role played by the molecules. In this book, the characteristics of a gas flow are determined from an assumed molecular model and the distribution of the velocities of the molecules.

Circle Reader Reply No. 91

HYDRODYNAMICS, Hugh L. Dryden, Francis D. Murnaghan and H. Bateman, 1956, Dover Publications, Inc., New York. 634 pp, \$2.50 (paper bound).

First published by the National Research Council of the National Council of Scientists, this volume offers an extensive coverage of classical hydrodynamics. It has an encyclopedic quality not often found in modern books, and it is still an outstanding source for classical material that does not quickly become obsolete. Much of its data, such as the extensive discussions of viscous flow, is not generally available elsewhere. The book is rendered even more valuable to the engineer, physicist and mathematician by an extensive bibliography of almost 3000 items classified according to topic and chapter.

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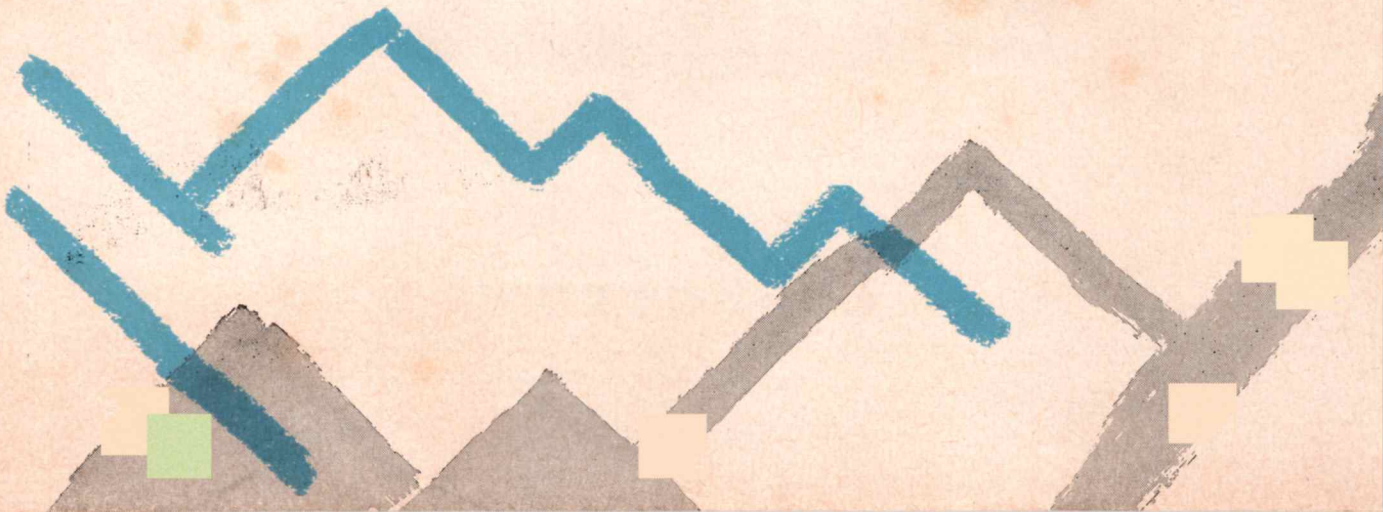
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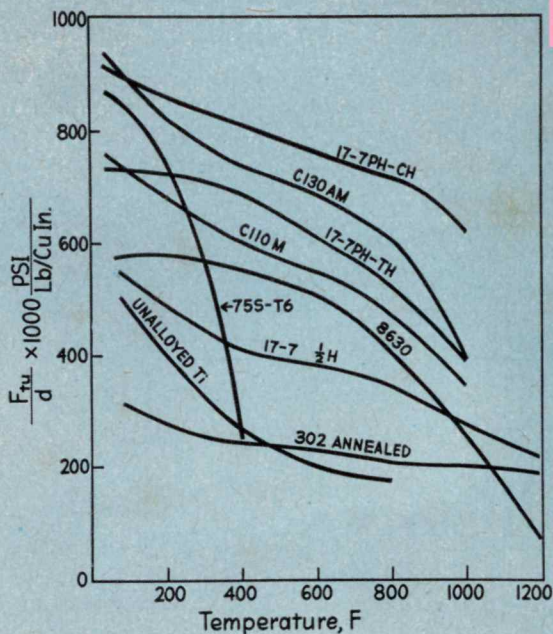


Figure 1—Strength-weight comparison on the basis of ultimate tension strength/density.

Advances in GAS TURBINE MATERIALS

JULIUS J. HARWOOD

Head, Metallurgy Branch
Office of Naval Research
Navy Department
Washington, D. C.

An intensive search is under way for new and improved materials able to withstand high temperatures. All possible avenues are being explored, and it is now realized that merely improving presently used alloying systems is not sufficient. More imaginative approaches are needed and are being taken.

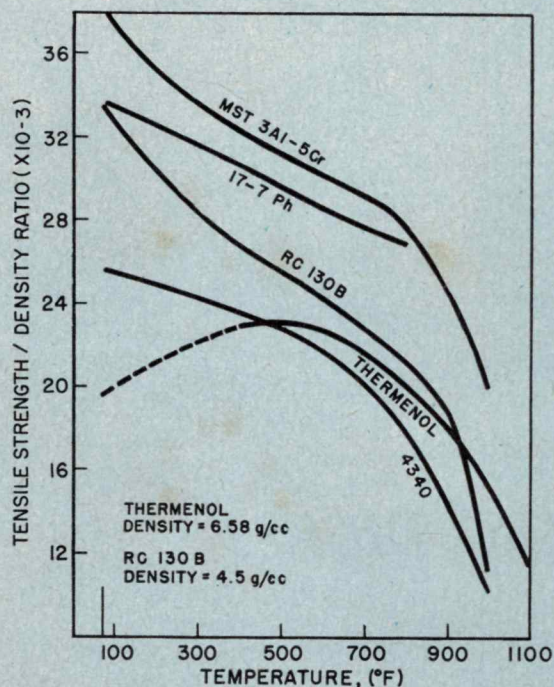


Figure 2—Comparison of Thermenol with other materials.

SINCE THE GAS TURBINE typifies most of our high-temperature materials problems and uses practically the entire range of materials as well as the bulk of our super alloys, it is appropriate to discuss recent trends in the development of improved high-temperature materials in relation to gas-turbine requirements and operation. There are few applications that demand such rigorous combinations of stress, temperature and critical dimensions.

Table I indicates the trend since the close of World War II in aircraft gas-turbine temperatures and performance characteristics. There has been a continuously increasing trend toward higher compression ratios and compressor temperatures, higher combustion temperatures and higher turbine inlet temperatures. The major obstacle limiting the use of higher

turbine-inlet temperatures is the lack of materials capable of withstanding turbine operating stresses above 1650°F. Higher combustion temperatures are desired to gain increased thrust and decreased specific fuel consumption, which can be translated into superior performance characteristics. Although most of the high temperature materials programs have been aimed primarily at the problems associated with aircraft gas turbines, increasing attention is being directed to small gas-turbine developments. Small turbines are being considered by the Navy for fire pumps, starter motors, auxiliary generators and propulsion units, main powerplants for ship propulsion, and rocket, missile and torpedo propulsion units. While for most of the units, increased operating efficiency is the chief objective of design and development programs, gas turbines for missile and rocket propulsion pose serious materials problems.

● ● Moderate Temperature Use (100°F - 300°F)

In general, the requirements for compressor blades are high resistance to corrosion, to erosion and abrasion and satisfactory creep and fatigue resistance. The most important design criteria has been creep resistance and the most frequent cause of service failures, fatigue. As compression ratios and compressor temperatures increase, aluminum alloys, with a temperature limitation of about 350°F, can no longer be used as a useful structural material. The hardenable straight chromium stainless steels (approximately 12 percent Cr) are commonly used for compressor blades and low alloy steels for compressor discs, Table 2.

The most publicized impact in the field of new compressor materials has been made by titanium and its

alloys. In fact, the virtues of titanium almost make it appear as a natural for compressor blades and wheels. The early over-optimism that prevailed about titanium has now settled down, and a more realistic appraisal of its potentialities as a structural material has evolved. The future position of titanium in the metal industry has been clearly demonstrated. There is no question that titanium alloys offer great promise for filling a need for materials in the range of 300°F-800°F and possibly to 1000°F, and a strong feeling exists among responsible officials that the successful application of titanium in military equipment will represent a technological break-through of major proportions.

Their lightweight, excellent corrosion resistance to certain environments, outstanding strength-weight ratio and fatigue strength, tensile strength ratio, and the availability of titanium ores show titanium alloys as materials of significant potentialities and applicability. But the major justification for the use of titanium in aircraft engines is to save weight. Its other virtues can be achieved by the use of more conventional materials more economically (at present prices). An increase in speed and performance characteristics of aircraft is generally accompanied by a manyfold increase in weight. Thus weight-saving becomes a vital factor in aircraft improvement either for military performance or commercial payload. Estimates indicate that for future aircraft designs, through the use of titanium alloys, several thousand pounds can be saved in fighters, and up to 10,000 pounds in bombers and transports. The military advantages of such weight savings are obvious.

The strength-weight superiority of titanium alloys in comparison with other competitive materials is illustrated in Figure 1. This outstanding advantage of

Year	Gas Temperature (°F)			Thrust (lb)
	Compressor	Turbine Inlet	Turbine Outlet	
1946	400	1400	1000-1100	5000
1950	650	1500	1000-1150	7500
1955	up to 850	1500-1700	1000-1200	10,000

Table 1 Trends In Gas Turbine Temperatures and Thrust

Temperature (°F)	Compressor Disk	Compressor Blades
400	14 ST Al alloy	Aluminum alloys & 403 stainless steel
650	14 ST Al alloy	Aluminum alloys & 403 stainless steel
850	Low alloy steels	Chromium stainless steel types

Table 2 Typical Compressor Materials

Gas Turbine

titanium has led to definite production applications as airframe materials and in jet engines, either as sheet or forgings. The current J75 engine uses titanium alloys for compressor discs, blades and other components. Titanium alloys also are currently under proof testing in other engines.

It would be difficult, in this brief review, to discuss in any detail the properties and fabrication characteristics of titanium alloys. Technical information on these subjects is being published continuously. One can summarize the titanium picture with the following remarks: within the space of ten years, a full-fledged titanium industry has been developed. Within the next few years, facilities will have been completed to permit a production capacity of 25,000 to 30,000 tons per year. The cost of titanium is being constantly reduced, the present price being approximately \$3.25 per pound for sponge. It is confidently anticipated that improvements in the present Kroll process and the introduction of low-cost processes will make titanium more economically attractive. Significant improvements have been made in the melting and fabrication of titanium alloys, such that both sheet and forging alloys for use up to 750°F are available. One of the most promising newly developed alloys is the 6Al-4V alloy, Table 3. The major problems associated with unalloyed titanium have been overcome, and the former difficulties associated with non-homogeneity and cracking of titanium alloys have been largely cleared up. Recognition of the military potential of titanium has led the U. S. Govern-

ment to supplement its sponge-producing assistance program with an expanded alloy research and development program, and a sheet-rolling program has recently been initiated to assist the alloy-producing and fabricating industry in order that improved alloys can be more speedily placed on a commercial basis. In considering the applicability of titanium, one should not lose sight of powder metallurgy techniques, since they afford a means whereby titanium can be made competitive with many of the highly alloyed materials.

● ● Thermenol

Thermenol, which was developed by the Naval Ordnance Laboratory, is an iron-base alloy containing primarily 16 percent Al and 4 percent Mo. Because of its outstanding oxidation-resistance and its non-strategic composition, it has attracted serious consideration as a compressor blade and sheet material. The alloy is weldable and hot formable and exhibits satisfactory corrosion resistance in salt-spray tests. In its preliminary state of alloy development, it exhibits high-temperature properties comparable to stainless steel. It appears to be useful as a structural material as high as 1000°F. The strength properties of thermenol in the as-extruded condition are shown in Table 4 and a comparison of thermenol with other materials is shown on Figure 2. It must be noted that the full potential of this alloy system is yet to be fully exploited. A number of commercial organizations are actively working on the fabrication and applications of Thermenol. Preliminary tests of Thermenol compressor blades have been quite encouraging.

● ● Sintered Aluminum Powder

An interesting Swiss development of a strong, high-temperature aluminum alloy called SAP (Sintered Aluminum Powder) has also attracted much attention. This new sintered aluminum product shows potentialities for use at temperatures of 800°F, which represents a major temperature increase over the best commercial high-temperature aluminum alloy. SAP is produced from fine aluminum powder by a combination of cold pressing, hot pressing and extrusion practice. SAP rods can be further cold- or hot-worked into sheets, shapes or drop forgings. In composition, SAP is equivalent to commercial 2S aluminum but it contains between 10 percent and 20 percent by weight of aluminum oxide. Typical room temperature mechanical properties are as follows:

Tensile Strength	50,000 psi
Yield Strength (0.2% offset)	32,000 - 36,000 psi
% Elongation	8 - 10
% Red. in Area	10 - 12.7

The strength and ductility properties can be varied by changing the amount, size, and distribution of the oxide phase.

Exposure to temperatures as high as 900°F for as long as 100 hours results in little or no change in the room-temperature tensile properties. This is believed to result from the effect of the finely dispersed oxide phase inhibiting grain growth and recrystallization.

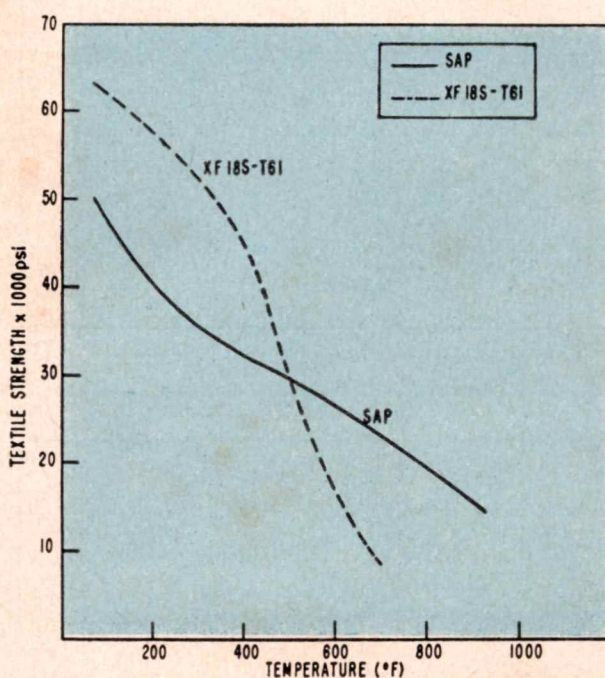


Figure 3 — High-temperature tensile properties of SAP and XF 18S-T61.

Table 3. Properties of Ti-6Al-4V Alloy.*

Temperature (°F)	Tensile Strength (psi)	Yield Strength (psi)	% Elongation	% R.A.
Rm. Temp.	150,000	140-150,000	10-20	50- 60
200	125-155,000	115-145,000	15-20	40- 60
400	110-145,000	100-125,000	17	50- 65
600	105-130,000	90-110,000	17-18	50- 70
800	95-115,000	80- 95,000	18-20	50- 70
1000	78- 92,000	60- 75,000	30-45	65-100

* Range of properties shown varies with heat treatment.

Table 4. Properties of Thermanol (as extruded).

Temperature (°F)	Tensile Strength (psi)	(0.2) Yield Strength (psi)	% Elongation	% R.A.
Rm. Temp.	82,900	66,800	1.9	3.8
500	77,800	45,900	3.3	6.1
600	81,100	43,400	4.4	8.1
800	84,700	45,000	6.8	10.1
1000	77,200	55,500	37.3	79.5
1200	47,900	30,200	54.2	91.0

The high-temperature tensile properties of SAP are shown in Table 5. Figure 3 compares these properties with those of our best high-temperature age-hardenable aluminum alloys XF18S-T61. In general, the strength and creep resistance of SAP at 600°F are as much as two to five times greater than those of conventional aluminum alloys. In addition, the fatigue properties of SAP are generally superior to those of aluminum alloys at temperatures greater than 400° to 500°F.

Its high-temperature strength properties have led naturally to consideration for possible use as a compressor blade material. SAP is also being evaluated for component applications in standard type engines. The Aluminum Company of America is developing a series of experimental alloys similar to SAP.

In addition to the potential importance of SAP as a structural material in its own right, SAP has provided a stimulus for the application of its basic principles to the development of other alloys. Work is underway with such metals as copper, nickel, cobalt, titanium, molybdenum and magnesium, and it is not improbable that a whole new series of Sintered Metal Products may emerge from current research and development efforts. If these efforts are successful, we may anticipate a decided improvement in the high-temperature-strength properties of relatively pure metals and considerable saving in alloying elements.

● ● Precipitation-Hardened Stainless Steels

Another ferrous alloy development that is receiving attention is that of precipitation-hardened stainless steels. Using less nickel than 18-8 and readily hardened by the precipitation of intermetallic compounds during heat treatment, these steels have attractive strength/weight ratios at room temperature. At temperatures to

700°F the ratio is comparable to the best of the light alloys. These steels can be formed by cold working or hot working in the soft condition and then treated in the temperature range of 850°F to 1400°F to develop strength characteristics equivalent to many carbon and low-alloy steels. Welding operations can also precede the final precipitation treatment, and the welding characteristics are similar to types 302 and 304 without requiring any preheat or postheat anneals. The high-temperature properties are good up to 800°F and in fact are superior to 18-8 stainless, low-alloy steels, some titanium alloys, aluminum alloys and magnesium alloys. Table 6 shows some typical room-temperature and high-temperature strength properties. These new stainless alloys are available in sheet, strip, bars, wires, forging billets, and some varieties are good casting alloys. Their corrosion resistance is generally superior to the standard heat-treatable stainless steels and under some conditions equivalent to 18-8. Their high elastic limit and endurance strength and good high-temperature properties make the precipitation-hardened stainless steels attractive materials for missile and aircraft manufacture. They are being considered for compressor blading, aircraft landing-gear parts, valves and other applications where resistance to oxidation and high stresses are required. They also appear to be promising spring materials.

Within the temperature limit of approximately 550° F, reinforced plastics must also be considered as potential structural materials. Their high strength/weight ratio and their high damping capacity make them interesting compressor blade materials, and preliminary spin tests of plastic compressor blades have been quite favorable. A variety of new resins are available, and work is underway to develop higher modulus fibers.

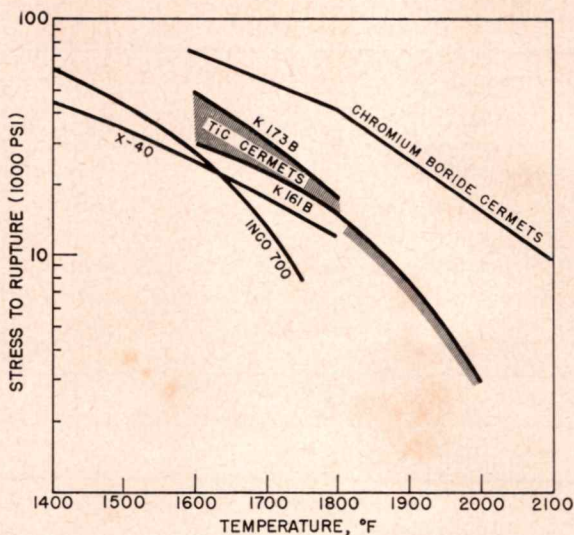


Figure 4—Creep-rupture properties (100 hr life).

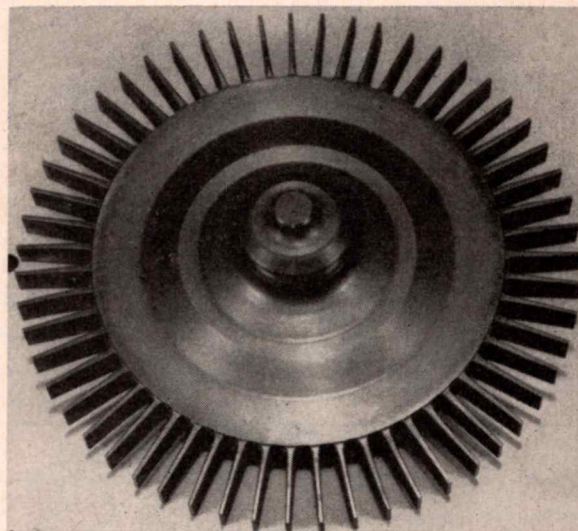


Figure 5—Spin test specimen.

Metal-coated glass fibers may be of interest along these lines.

Ductile vanadium has been developed in recent years, and vanadium alloys should also receive consideration as a potential compressor material. The mechanical properties of vanadium are shown in Table 7. The modulus/density ratio of vanadium is equal to that of steel and higher than for titanium. It has good corrosion resistance and good high-temperature strength. Up to 1100°F the tensile strength of vanadium is superior to type 304 stainless and between 1100° and 1800°F it has comparable strength. Vanadium alloys would undoubtedly have higher strengths. The poor resistance to oxidation of vanadium would require the use of protective coatings.

The ever-pressing desire to reduce weight has led to the design and development of "sheet metal engines." Moderate temperature, high strength sheet materials are receiving increasing attention. Titanium alloys, stainless and alloy steels are competitive materials, and the use of sandwich construction in compressors is becoming an attractive possibility. By such design features the temperature limitations of aluminum alloys has been shifted to appreciably higher temperature.

● ● High Temperature Alloys (1500° - 1800°F)

A major share of our high-temperature materials research and development effort is directed at the turbine stage of jet engines, since this is where potential gains in military performance can be achieved. As indicated earlier, present turbine wheels operate up to about 1650°F. The immediate goal is to raise the temperature to 1800°F, with the ultimate objective of going as high as possible.

The turbine blades are subjected to the most punishing conditions of stress, temperature and environment of all the turbine components. Turbine-blade materials

must have high oxidation and erosion resistance, high creep and rupture strength, high fatigue strength and resistance to thermal shock. Although creep rupture strength is still the main design criterion, fatigue strength and thermal shock resistance are becoming increasingly important in advanced design engines.

Current research programs are being concentrated along four major directions: (1) development of improved nickel and cobalt base alloys; (2) development of cermets (metal-bonded refractory compounds); (3) development of new refractory alloy systems such as molybdenum, chromium and niobium (columbium); and (4) development of artificial cooling techniques.

The chemical compositions of representative turbine-blade materials are shown in Table 8. They fall, generally, into three groupings; cobalt-base alloys, nickel-base alloys and nickel-chrome-cobalt alloys.

Recent improvements in nickel-base alloys has permitted an increase in turbine-inlet temperature to 1650°F with possibilities of going to 1700°F-1750°F in a future time period. These nickel-base alloys derive their high-temperature strength properties from the age-hardening reactions involving aluminum and titanium. The use of vacuum-melting techniques has enabled, in large part, the development of these superior nickel-base alloys and the claim has been made that, in the future, the bulk of such alloys will be vacuum melted. It has been claimed that vacuum melting results in better forgeability and greater recovery of sound material; superior fatigue limit/tensile strength ratio; greater ductility; greater high temperature strength properties; greater resistance to intergranular penetration; and better overall combination of properties.

Typical example of nickel-base alloys include Inco 700, Waspalloy, M252, GMR 235 and other proprietary alloys.

Similar developments in cobalt-base alloys are in

progress, and it is anticipated that improved alloys will be available for 1600°F-1700°F turbine operation.

● ● Cermets

A great deal of attention has been focused on metal-bonded carbides, borides, oxides, silicide, nitrides, and so forth, popularly called cermets. The development of cermets was centered around the attempt to take advantage of the high-temperature strength of the ceramic or refractory compound phase and the ductility and thermal shock resistance of the binder.

As of this time, the most highly developed cermets are the cemented titanium carbide grades. Nickel-base alloys are the most prevalent binder materials. Earlier grades had metal binder contents ranging from 20 percent to 30 percent, but because of low ductility and impact resistance present grades are running from 50 percent to 70 percent binder content. These metal-bonded titanium carbides exhibit strength properties up to 1800°F and oxidation resistance and thermal shock characteristics which makes them potentially useful turbine blade and nozzle guide-vane materials. Their high-temperature strength properties are shown

in Figure 4 and are summarized below:

Temperature °F	Stress to Rupture in 100 hours
1600	up to 44,000 psi
1700	25,000 psi
1800	up to 17,000 psi

Titanium-carbide-cermet turbine blades have satisfactorily passed 100-hour hot-spin tests, and the carbide cermets have also exhibited excellent results in nozzle guide-vane tests. Other cermet materials that are of interest include the chromium-alumina, molybdenum-disilicide, nickel-aluminide and the metal-bonded Cr₂Ti types.

The major problems in the use of carbides and other cermets for turbine blades or guide vanes are low ductility, high notch sensitivity and low impact resistance. Low ductility, in part, has been circumvented by modifying the current fir-tree root design of turbine blades. New design concepts have been developed by the NACA which avoid the stress concentrations at the fir-tree serrations and which compensate for the lack of ductility in the cermet by the use of ductile shims or retaining pins. These features provide better load

Table 5 High-Temperature Properties of SAP.

Temperature (°F)	Tensile Strength (psi)	Yield Strength (0.2% offset) (psi)	Elongation in 2.0 in. (%)
72	50,000	34,200	10
212	40,000	34,000	10
392	32,800	30,500	8
752	21,300	20,600	4
932	14,200	13,500	2

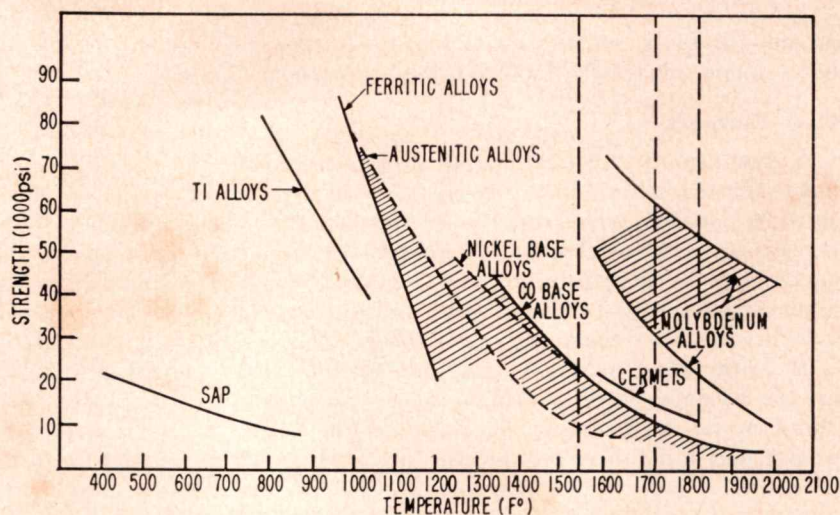
Table 6 High-Temperature Properties of Precipitation - Hardened Stainless Steels (17-7 PH).

Temp. (°F)	Tensile Strength (psi)	Yield Strength (psi)	Elongation (%)	100-hour Stress Rupture Life (psi)
70	206,500	184,500	9	—
500	180,000	153,000	6	—
600	—	—	—	162,000
900	136,000	102,500	12	73,000
1000	108,500	67,500	12	—

Table 7 Mechanical Properties of Vanadium.

Treatment	Tensile Strength (psi)	Yield Strength (psi)	Elongation (%)	Red. in Area (%)
Annealed	55,000-75,000	42,000-65,000	26-38	66-82
Cold Rolled				
" (60%)	107,000	101,000	2-5	—
" (75%)	117,000	110,000	2-5	—
" (80%)	155,000	142,000	2-5	—

Figure 6 — Comparison of stress to rupture properties of molybdenum base alloys, as compared with other high-temperated materials.



distribution, and root failures in spin tests disappeared.

The low impact resistance is the most serious limiting factor in the application of cermets for turbine buckets or guide vanes. The high degree of foreign object damage in aircraft gas turbines requires that blade and vane materials have adequate impact resistance. This problem is severe enough to cause serious doubt in many quarters about the practical use of cermets in large turbines. However, continuous improvement is being made in increasing the ductility and impact resistance, and recent encouraging results indicate that the properties of cast super-alloys are being approached by the cermets.

The cermets, however, should be promising materials for small gas turbine applications. Integral disc and blade titanium carbide turbine wheels have been successfully spin-tested by at least two carbide producers. In addition, spin-testing of slotted-disc titanium carbide wheels were recently completed, Figure 5, based upon the Boeing 502 turbine design. These wheels were tested at 1600°F and performed most creditably. A test rig has been constructed at the Naval Air Material Center to continue such tests up to 2000°F. If the simulated wheels perform satisfactorily, actual airfoil wheels will be tested. It is suggested that the application of cermets for small gas-turbine application be given serious consideration, since they hold great promise for increasing turbine temperatures. It would seem, at first glance, that small gas turbines would not be subject to the same degree of foreign object damage as aircraft gas turbines.

Chromium base alloys have been developed which exhibit good high temperature properties up to 1800°F. But such alloys suffer from the same disadvantage as cermets, namely low ductility. However, recent work on the preparation of ductile chromium and more ductile chromium-base alloys hold out some real hope for interesting developments in this field.

● ● Super High-Temperature Materials (1800°F and Up)

A new group of chromium boride cermets has recently been developed which, based on their strength,

thermal shock, and oxidation resistance at high temperatures, show significant promise for use up to 2100°F or higher temperatures. At 1800°F, the chromium boride cermets are twice as strong as the titanium carbide grades; or at the same strength level they exhibit a 200°F superiority. Their properties are shown in Table 9, and a comparison of the borides, carbides and nickel base alloys is shown in Figure 4. This is still an early development and an evaluation of gas-turbine components will be initiated shortly.

The outstanding high-temperature properties of molybdenum and its alloys have attracted considerable attention for the use of these materials for gas-turbine applications and has led to intensive alloy development programs. In the temperature range of 1600°F-2000°F, pure molybdenum exhibits better rupture strength than the best cobalt, nickel or Cr-Co-Ni-Fe base alloys, while the molybdenum base alloys that have been developed have strength properties at 2000°F superior to the commercial gas-turbine blade materials at 1600°F. These properties are unequalled by any other material tested to date.

The 100-hour stress to rupture properties of the best molybdenum alloys are shown in Table 10 and are compared with other gas-turbine materials in Figure 6. Unfortunately, a major obstacle limits the widespread use of molybdenum alloys for turbine applications. Molybdenum and its alloys undergo rapid oxidation and satisfactory protective coatings are urgently needed. Much effort is proceeding along these lines and coatings of nickel-chromium combinations appear promising for use up to 2000°F. The rewards from the solution to the problem of the protection of molybdenum alloys would be a potential increase in gas-turbine operating temperatures of approximately 400°F. Several coating systems are now undergoing engine testing.

Recent announcements of increased availability of columbium ores have led to increased attention to columbium alloys as high temperature structural materials. Like molybdenum, columbium exhibits outstanding strength properties at 1800°F. Alloy development

programs are now underway, but are still in an early stage. Columbium most likely will need to be protected against oxidation, but unlike molybdenum it does not have a volatile oxide.

Although it does not come under the heading of material developments, brief mention must be made of the possibilities of cooling methods to achieve higher temperatures. It has been adequately demonstrated that direct air cooling or transpiration (sweat-cooling) can lower metal temperatures quite markedly. The limitations of materials will ultimately necessitate resorting to cooling methods if super high-temperatures become a reality.

As a result of the intensive research programs of the past several years significant contributions have

been made to the field of new materials developments. However, as the service-operating temperature continuously increase, and as the operating conditions grow more severe, we are approaching the limitations of all materials. This must be recognized by designers, and new design concepts must be developed to overcome these limitations. Only through the integration of design and materials will the full potential of the new materials developments be realized for high performance, high temperature gas turbines and related powerplants.

END

The views and opinion expressed are those of the author and do not necessarily reflect the official attitude of the Office of Naval Research or the Navy Department.

Table 8. Chemical Compositions of Representative High - Temperature Alloys.

Alloy	Cr	Co	Ni	W	Co	Mo	Fe	Ti	Al
Cobalt Base									
Vitallium	27	64	2			5	2		
X40	25	55	10.3	7.4			1		
S816	20	43.7	20	4	3.75	4	2.8		
Ni-Cr-Co Base									
NI55	21	20	20	2	1	3	30		
Refractalloy 26	18	20	37			3	18	2.8	0.2
Nickel Base									
Inconel X	15		72.5		1		7	2.5	.7
Nimonic 90	19.5	19.5	55.5				0.5	2.5	1.2

Table 9. Chromium Boride Cermet Stress - Rupture Properties.

Temperature (°F)	10 hour	100 hour	1000 hour
1600	150,000 psi	71,000 psi	36,000 psi
1800	78,000 psi	41,000 psi	21,500 psi
2000	24,000 psi	16,000 psi	11,000 psi
2100	13,200 psi	9300 psi	6500 psi

Table 10. 100-Hr Stress to Rupture Properties of Molybdenum-Base Alloys.

Temperature (°F)	1600	1800	2000
Stress Relieved	73,000 psi	66,000 psi	50,000 psi
Recrystallized	35,000 psi	28,000 psi	21,000 psi

ROBERT W. BASS
Department of Mathematics
Princeton University

A new synthesis procedure for on-off control systems is presented through which the delays arising from time-lag and hysteresis in the relay or contractor can be completely eliminated. Important advantages to missile control systems include simplicity, ruggedness and economy.

Improved On-Off STABILIZATION SYSTEMS

ON-OFF OR DISCONTINUOUS automatic control systems have been successfully used in a variety of terrestrial and aeronautical applications. Early examples are the simple relay servomechanism and the pneumatic aileron and tailplane controls of guided missiles of the V-1 type. More recently, jet-reaction control systems have been applied to experimental vertical take-off aircraft, and to the stabilization of ballistic missiles (such as the *Viking* rocket after burnout).

These systems, diverse in their details, share a common schematic description: they are all nonlinear feedback control systems, and the mathematical theories of their operation are identical. But this underlying theory is far more difficult than that of the conventional linear servosystem. In fact, the lack of a truly effective analysis and synthesis technique has retarded the development of the field. However, the on-off systems possess important advantages of simplicity, ruggedness and economy, which render their investigation desirable.

Designers of discontinuous automatic control systems have come to recognize two basic problems. The first is the problem of stabilization. By stabilization one means the arrangement of the feedback or feedbacks in such a way that the output (or motion of the controlled object) follows the input (or controlling signal) with an error that tends rapidly to zero, that is, the servosystem must not hunt.

● ● Hunting

What causes on-off or relay control systems to hunt? For most systems, the answer is: delays. An ideal on-off system cannot hunt. But in a physical system there are always delays that cause the output

to overshoot the input and so produce instability. For example, in a relay servo the delays allow the rotor to store kinetic energy and this stored energy offsets that dissipated by friction. The oscillations die out only until the energy stored per period is just equal to that dissipated by friction. At this point a self-sustained oscillation occurs.

In a schematic diagram, it is convenient to locate all time-delays and hysteresis in the relay or on-off element; however, these delays can actually be located anywhere in the system, without changing the analysis. For example, in a jet-reaction control system the delay in the thrust build-up of the rocket motor is most significant, and, if considered to be constant, can be added to the relay time delay.

These delays are particularly important in the applications to guided missiles, because the great velocities involved drastically exaggerate the time scale.

Our principal result is a new method for designing on-off systems in which, as will be explained later in detail, the delays in the system are completely eliminated. This method is based upon some new results of the author in the theory of discontinuous difference-differential equations. These results are not elementary, but their consequences can be easily visualized, and in theory at least, they completely solve the problem of stabilization.

The second basic problem in control design is that of optimization, namely, that of arranging a nonlinear switching computer or other device to modify the system feedbacks in such a way that the error is brought to zero in the shortest possible time consistent with the available torque sources. For ideal systems, that is, those without delays, the solution has been known for some time, thanks to the work of Mac-

$t_d < 2\bar{e} < t_d^*$		
$\Delta\bar{e} < \Delta\bar{e}^*(\bar{e} - t_d/2)$	$\delta < \sigma$	No oscillations
	$0 < \sigma < \delta$	Hard oscillations
$\Delta\bar{e} > \Delta\bar{e}^*(\bar{e} - t_d/2)$		Soft oscillations

Table 2—Time Delay Small With Respect to Dead Zone Width

Table 1—Time Delay Large With Respect to Dead Zone Width

$t_d^* < 2\bar{e} \leq 1$	
$\Delta\bar{e} < \Delta\bar{e}^*(\bar{e} - t_d/2)$	No oscillations
$\Delta\bar{e} > \Delta\bar{e}^*(\bar{e} - t_d/2)$	Soft oscillations

Donald, Bushaw, La Salle, Rose and Bellman. The result, perhaps unexpected, is that an optimized relay servo without delays can outperform any other type of linear or nonlinear servosystem having the same maximum available torque. But as MacDonald pointed out, because of the delays actually present it would be necessary in practice to employ dual mode control; that is, when error had nearly reached the hunting stage, it would be necessary to replace the relay servosystem by a linear control system. The resultant dual mode system is of course complex and expensive and seems not to have been widely employed.

However, if the system were designed by the method proposed by the author, which involves only the addition of a single extra feedback loop, it would be equivalent to an ideal system, and an optimizing device could then be added without the necessity of dual mode control. In other words, it is now practical to construct simple relay servosystems that are not only stabilized but are optimized as well.

• • Ideal Servo

In order to clarify these ideas, let us first consider the standard ideal relay servomechanism as depicted schematically in Figure 1. Here the reference variable or input r is given and it is desired that the controlled variable or output c should follow it. By means of a feedback loop the controlled variable from the motor M is compared with the reference variable, and the difference is measured. This difference is the error e . It operates the relay that controls the motor. In Figure 1, the relay is represented as an ideal relay except for the presence of a dead zone of width $2\bar{e}$.

An actual relay also possesses a time delay, t_d , so that in effect the signal that controls the relay is not the present error but the error at t_d seconds in the past.

Moreover, the relay output is not strictly a single-

valued function of the error. This is due to a hysteresis phenomenon caused, for example, by the fact that there is a difference between the pull-in and drop-out currents of relay solenoids. Consequently, the characteristic of the output F of the relay is as shown in Figure 2.

The effect of this hysteresis on the transient response of c can be seen in Figure 3. The dead zone is not centered on the input r_o but shifts upwards and downwards by an amount $\Delta\bar{e}$. Consequently the controlled variable overshoots and is not damped rapidly enough. If the hysteresis is at all significant in comparison with the dead zone width, the self-sustained oscillation called hunting will result.

The effect on the transient response of time delay is qualitatively similar to that of hysteresis, Figure 3. The principal difference is that the amount of the shift is no longer constant, but decreases as, in each successive oscillation, the velocity with which the controlled variable tends to the reference variable decreases.

Until recently, the behavior of even such a simple servomechanism as that shown had not been fully worked out. In fact, if one employs the methods of Hazen, Weiss and Feldbaum, one arrives (after lengthy but elementary calculations) at a certain transcendental implicit equation that determines the system's behavior. But this equation in general has more than one solution, and some of the solutions are extraneous. Consequently, a discussion of the equation is not entirely straightforward. However, a full analysis of it is given in Reference 1.

The results are given in two tables. Table 1 refers to the case when the time delay is large in relation to the dead zone width. There are then two subcases.

1) Suppose first that the hysteresis is small in relation to the dead zone and time delay ($\Delta\bar{e} < \Delta e^*$

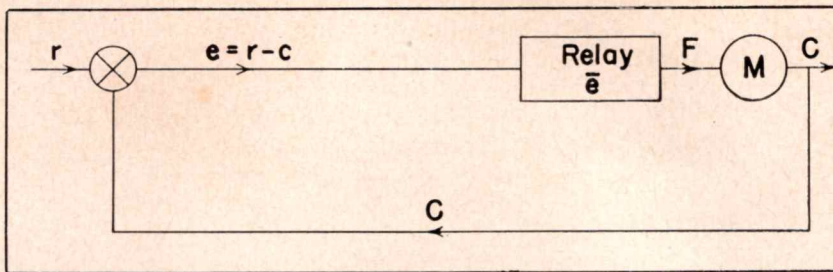


Figure 1—Ideal relay servomechanism.

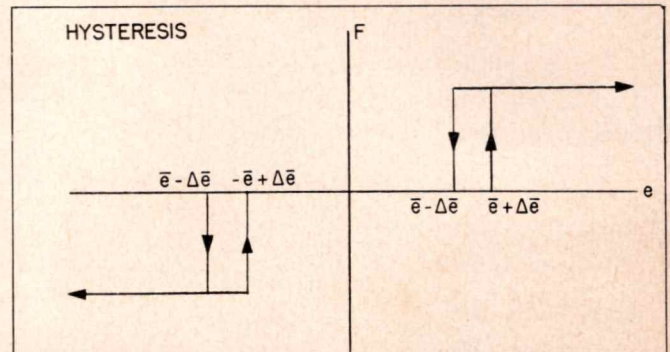


Figure 2—Characteristic of the relay output.

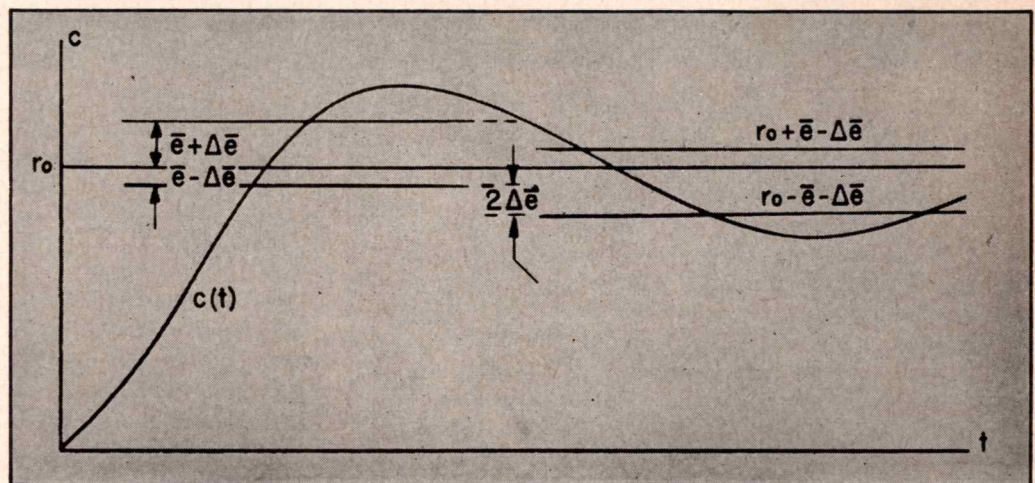


Figure 3—Effect of hysteresis on transient response.

$(\bar{e} - t_d/2)$. Then there are two further possibilities.

a) If the time delay is small ($\delta < \sigma$) the system behaves roughly like an underdamped linear oscillator, the output coming to rest within a distance $2\bar{e}$ of the input after a finite number of oscillations. This represents the desired performance.

b) But if the time delay is large ($\delta > \sigma > 0$) we get what is called a hard oscillation. This means that for small errors the system is well damped, but for errors exceeding a certain critical value the resultant oscillations will not die out.

2) However, if the hysteresis is large in relation to the time delay and dead zone, even small errors result in hunting. This is called a soft oscillation. Table 2 illustrates the case where the time delay is small in relation to the dead zone. Here the system either hunts or has a soft oscillation according as the ratio

of the hysteresis to a certain function $(\Delta e^*/\Delta \bar{e})$ of the dead zone and time delay is less than or greater than unity.

• • Anticipatory Control

When the analysis of Tables I and II is applied to a specific system, it usually reveals that no physically feasible values of the system parameters will produce entirely satisfactory performance. Hence recourse must be made to stabilizing networks or devices.

The conventional means of stabilizing relay servo-systems is shown in Figure 4. It is called anticipatory control. One first adds a rate gyro or differentiating network to obtain the rate of change of the error, called the error-rate. The error rate, after being amplified by a factor k , is then added to the error, and their sum Σ is fed into the relay.

Hitherto it was not known except by experiment how large a value of k was necessary to prevent hunt-

ing. In Reference 1, a formula was found giving the minimum necessary value of k as a function of the parameters $\bar{e}$, $\Delta\bar{e}$ and t_d . Most relay servos are now stabilized by the anticipatory method and so this formula should be useful in the preliminary design stages.

However, there is a drawback to this method. Usually anticipatory control causes the output to chatter up to the input, that is, the relay operates consecutively more than once with the same polarity. Although there is then no hunting, the quality of the transient response is poor. Moreover the settling time may be protracted.

Accordingly, the maximum value of k that can be

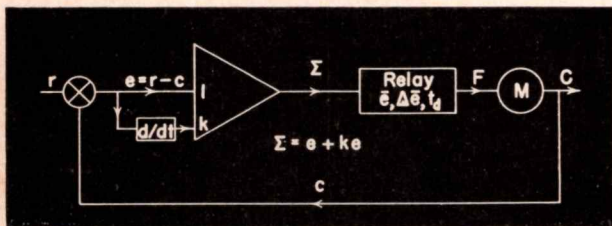


Figure 4—Anticipatory control.

used without producing chattering was investigated. Another formula was obtained and Figure 7 compares the two sets of curves. The straight lines give the minimum k necessary to suppress oscillations and the dotted curves show the maximum k that can be used without chattering.

But what if chattering is considered to be undesirable and the preliminary design shows that it will occur?

● ● Predictor Algorithm

At this point luck enters the picture. For, after some months of work it was found that certain identities that are known to hold for the solution of homogeneous linear differential equations with constant coefficients can be generalized to inhomogeneous piecewise-linear difference-differential equations. These identities form the basis of what the author calls the predictor algorithm. Essentially, they enable one to predict accurately what the relay system will do for the next few seconds, given its present behavior. This is not an approximation, but is theoretically exact. Consequently, one can arrange the feedbacks to give a true prediction rather than just an anticipation. And by means of this prediction the delays in the system can not only be counteracted but in fact eliminated.

Figure 6 depicts what must be done. A second feedback loop is added and feedback from the relay itself is used. In case of dynamic or slowly varying inputs, the input rate must also be used as an additional reference variable. These feedbacks are added together in certain proportions and the resultant sum Σ goes to the relay. The important point is that the coefficients of proportionality are so chosen that the sum now gives the value of the error as it would be t_d seconds in the future for the corresponding ideal system. This time lead in the signal to the relay now balances the

delay in the relay, so that in effect time delay is cancelled from the system.

The proper coefficients of feedback k and k_1 can be determined immediately by means of the predictor algorithm. Essentially one must first integrate the differential equations of the corresponding conventional system, for example, by means of the Laplace transform. In this way the transient response of the system is obtained as a linear form in the initial conditions of the error, the error rate and the signal from the relay. The coefficients of these initial conditions will of course be functions of the time. If however one replaces the time in these coefficients by the constant value of the time delay, t_d , then the ideal values of the coefficient of the corresponding feedbacks will be obtained. This process is straightforward and can always be carried out.

Finally, it can be shown that if $\Delta\bar{e}$ is added to the coefficient k_1 , then the hysteresis will also be eliminated.

Thus, the servomechanism of Figure 6 will respond to step and ramp (or constant velocity) inputs in exactly the same manner as that of the simple idealized servo of Figure 1. Of course this analysis, as do virtually all nonlinear servo analyses, neglects noise. But this may not be a limitation, since no derivative other than the first is employed.

The predictor algorithm can be applied to some specific missile control systems which are now described in the literature. Consider for example the jet-reaction control system that is used to stabilize the *Viking* rocket during its coasting period after burnout. This system is schematically identical with the relay servo of Figure 1. However, M now represents the missile dynamics, and there is no longer a viscous friction term in the differential equations. At present this system is damped by an anticipatory type of control similar to the error-rate feedback of Figure 4.

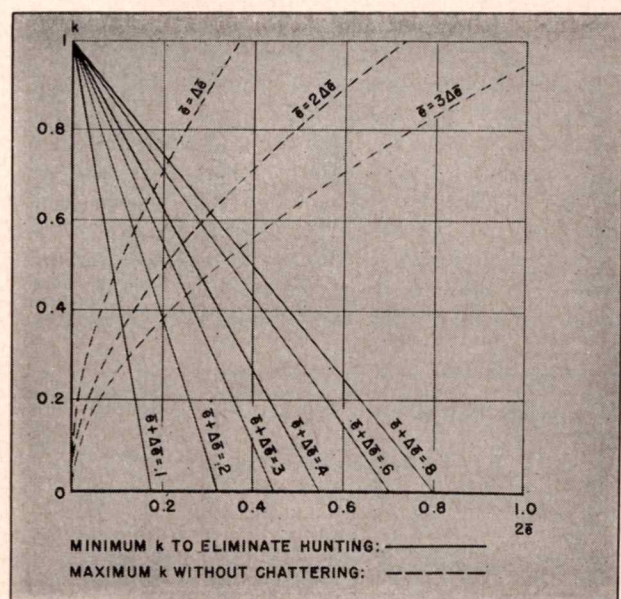


Figure 5—Effect of amplification factor on hunting and chattering.

Stabilization

We have been told that the damping did not completely remove the hunting. Yet in this case a high quality of stabilization is not superfluous. For the *Viking* is used as a vehicle to carry measuring and recording instruments which are in operation during its coasting phase.

● ● Applications

The author has been informed that later versions of the *Viking* stabilization system employed a larger amount of damping, sufficient, in fact, to suppress oscillations. It seems probable that this also introduced chattering, and in view of the factor of instrument stability, one might suggest consideration of the possibility of using a predictor network for applications of this type. One could then obtain adequate damping with a good quality of transient response as well.

The *Viking* rocket after burnout is essentially a pure inertia, that is, a ballistic missile. However, on-off control has also been applied to aerodynamic missiles, for example, the German V-1. An extensive study of such systems has been made in Reference 7. These systems all involve chattering. By the method described, one may calculate the amounts of error, error-rate and relay feedback necessary to stabilize these systems by the predictor method, Reference 3.

Finally, let us outline the application of the prediction algorithm to the rather complex system described in Part III of Reference 7. This system involves three degrees of freedom, which are essentially the deviations from their values in a straight flight path of the angle of attack of the wing, of the angle of the missile with a horizontal plane, and of the missile velocity. Here it is not yet feasible to use feedback of all three variables. In fact, the deviation θ of the missile from horizontal is most convenient to record, and so a feedback of

$$\theta + k \left(\text{rate of change of } \theta \right)$$

is employed. After a lengthy analysis, Reference 7 proves that it is best to take $k > 0$.

A simple method of obtaining and extending such results concerning anticipatory control can be based on the predictor algorithm. In addition to the feedback from the on-off element, there are six other feedbacks that could be employed. Suppose one calculates for these seven coefficients the values that should be used in order to eliminate fully the delays.

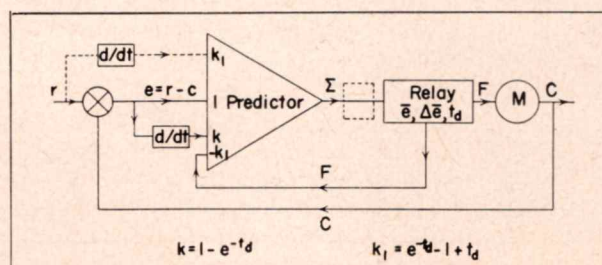


Figure 6—Perfectly stabilized servo.

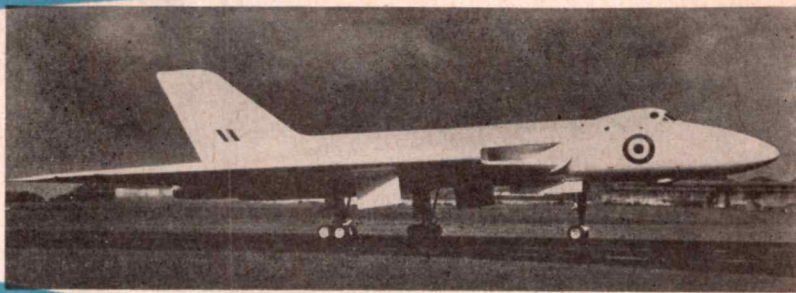
But suppose it is feasible to use feedback from only three of these variables. In order to obtain an anticipatory effect, one should then at least give the coefficients of each of these variables the same algebraic sign (positive or negative) as that determined by the predictor algorithm.

In summary then, for systems with several degrees of freedom it may be preferable to use the predictor algorithm only in part, that is, to design an anticipatory stabilizer. However for many typical missile and aircraft control systems it appears feasible and often desirable to effect full stabilization by means of the predictor network. And finally, if a very high performance servosystem is desired, one would recommend a relay servosystem that is first stabilized by a predictor network and to which an optimizing switching device is then added. Such a device should be added in the position of the dotted box shown in Figure 6.

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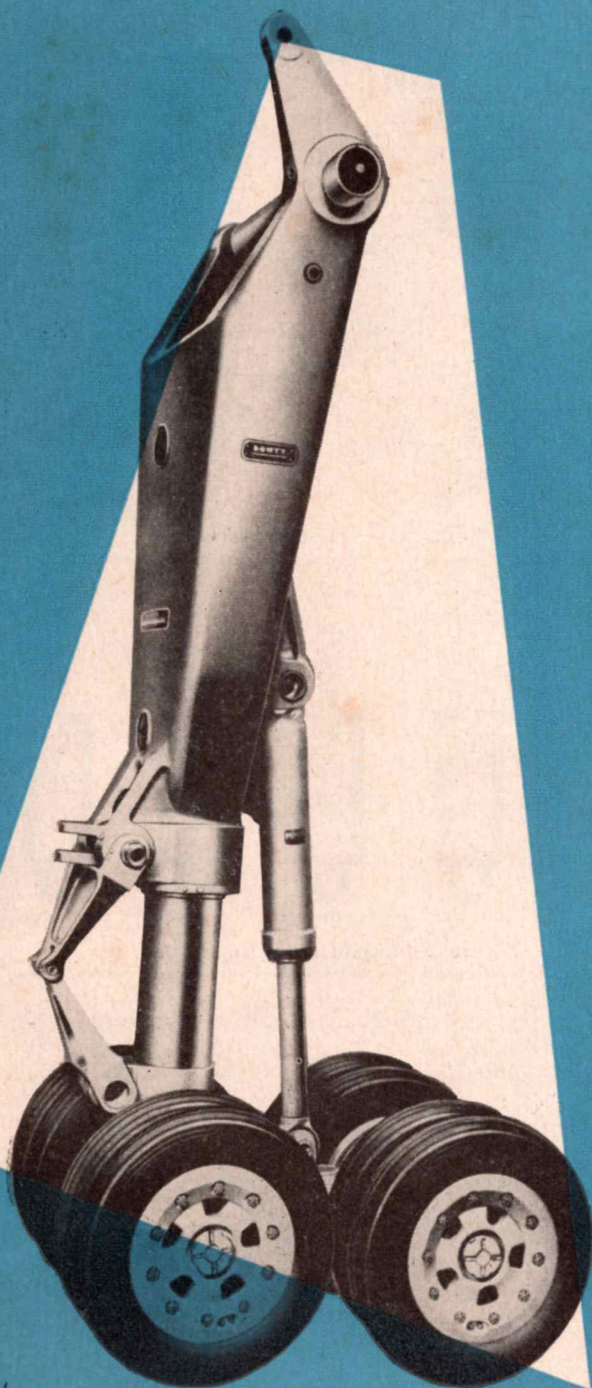
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Liquid Spring Principle
Applied to



LANDING GEAR DESIGN

By means of a special gland able to contain a liquid under high pressures, lightweight and compact landing gears can be designed having simplified linkages and short strokes.



T. M. KEMP

Engineering Department
Dowty Equipment Co. of Canada Ltd.
Ajax, Ontario

THE PURPOSE of an aircraft landing-gear arrangement is twofold: to dissipate the kinetic energy of vertical velocity on landing, and to provide ease and stability for ground maneuvering. The design of landing gears to perform these functions efficiently has become quite complex with the increasing loads and diminishing storage space of today's aircraft.

Consider first the problem of shock absorption! Two types of shock absorbers are in general use, the oleo-pneumatic and the liquid spring. In aircraft use for over 40 years, the familiar principle of the oleo strut needs no explanation. The liquid-spring shock absorber, however, is a relatively recent development. Designed by Dowty Equipment, it has gained wide acceptance in Britain and Europe and is used in the Canadian Avro CF-100 Fighter and C-102 *Jetliner*, and most recently in the Lockheed F-104 Fighter.

● ● Mechanics of Liquid Spring

As the name implies, the liquid spring uses the compressive properties of liquids as a springing medium. The same fluid volume is used in a dash-pot effect to control the recoil stroke. The liquid spring, illustrated in Figure 1, is simple in construction, comprising a cylinder, piston rod, piston and gland. Springing is accomplished by forcing the piston rod

Landing Gear

into the cylinder, displacing fluid volume thereby compressing the liquid. Energy is dissipated during the compression stroke by transferring fluid to the opposite side of the piston past the central spring-loaded valve and a smaller open orifice in the piston. On the recoil stroke, the spring-loaded valve closes, restricting flow to the small open orifice, thus damping the outward movement of the piston rod, see Figure 2.

The spring-loaded valve gives the shock absorber different springing characteristics for high and low dynamic loading. This is especially important on nosewheel landing gears which require a hard shock absorber when taxiing, to prevent a slow pitching movement, while requiring a softer shock absorber to avoid exceeding the maximum permissible airframe reaction on landing. The velocity of shock absorber closure when taxiing is low, of the order of 1 or 2 feet per second. Consequently, the pressure drop across the small open orifice is not large, since the pressure drop is proportional to the square of the velocity. This pressure differential is not enough to overcome the spring behind the valve, and thus the orifice used for taxiing is the small one; hence the shock absorber is hard and successfully resists pitching. On landing, the velocity of closure is much higher, and the pressure differential across the piston builds up until it reaches a predetermined value, overcoming the spring. The valve then opens and the large orifice comes into use, giving a soft shock absorber.

The two curves shown in Figure 3 graphically illustrate the valve function. Curve *S* is the static spring-load of the shock absorber, that is, the non-dynamic curve with no dash-pot effect. In case *A* there is a fixed compression orifice and the dynamic curve follows a straightforward dash-pot curve, whereas case *B* illustrates the curve given by a shock absorber with a valve. Resistance to movement is proportional to the pressure drop across the piston, and at first there is only a small orifice so that the curve rises steeply until the pressure differential reaches a point at which the spring behind the valve is overcome and the valve opens. The orifice is now the large one and the curve therefore flattens out. As the velocity falls, owing to the absorption of the energy, the dynamic curve approaches the spring curve until they meet, at which point the aircraft has come to rest vertically. The energy absorbed by a shock absorber is given by the area under curve *D*, and it will be seen that the area under this curve for case *B* is greater than that under the curve in case *A*. Thus for the same stroke and the same spring curve, and therefore the same size and weight of shock absorber, the energy absorbed is greater when using the valve, and taxiing and landing characteristics are improved. Note that a shock absorber of 100 percent efficiency would follow the sides of this rectangle, and the actual area under the

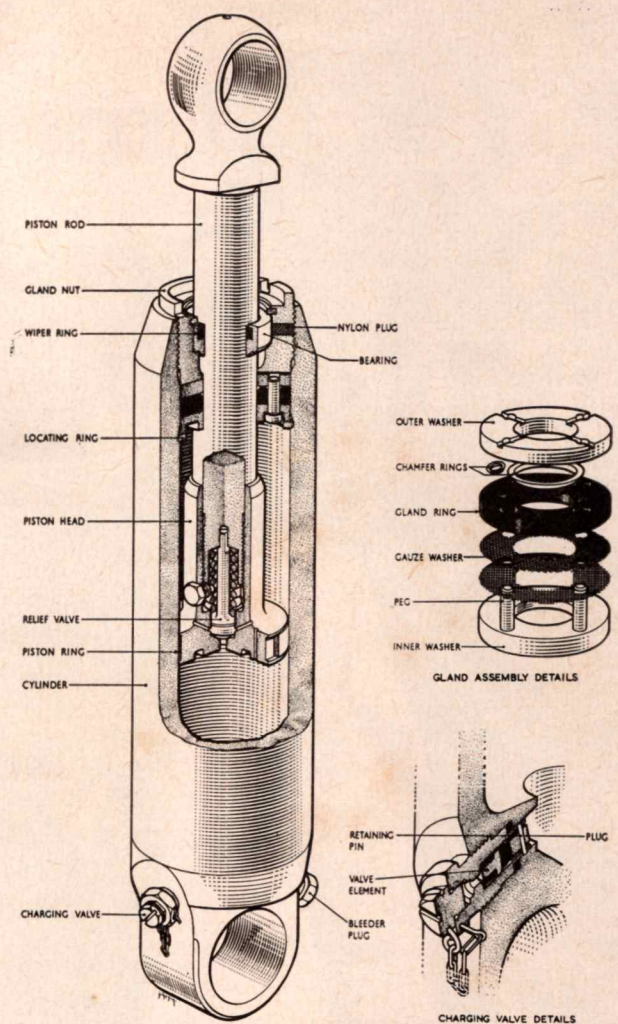


Figure 1—Shock absorber.

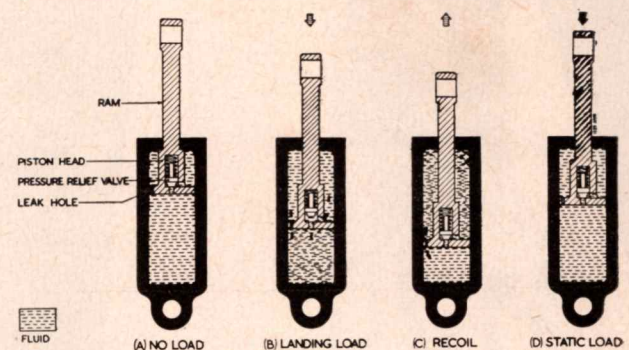


Figure 2—Liquid spring operation.

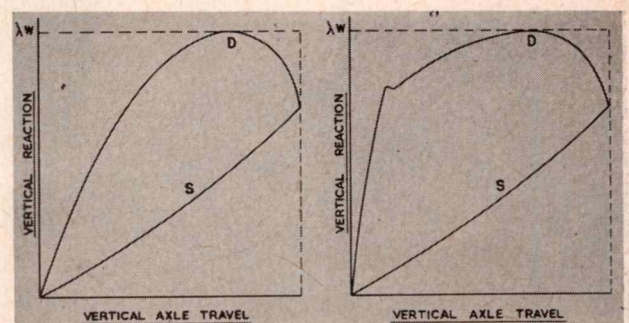


Figure 3—Liquid spring reaction curves.

dynamic curve divided by the area of the rectangle is taken as a measure of the shock absorber efficiency. An efficiency figure of 97 percent has been achieved on a landing gear using a liquid-spring shock absorber.

● ● Application

The practical use of liquids in compression was made possible only by the development of a high-pressure gland. The design requirements for this gland were to confine liquids at pressures of 50,000 psi (the maximum working pressure of the liquid spring) without exerting excessive friction loads on the piston rod. At the same time, the gland had to have a reasonable service life. The gland developed is illustrated in Figure 1. This design is based on the principle of the unsupported area. In this arrangement the dowels, which are rigidly attached to the inner washer, pass through the gland ring and approximately half way through the outer washer. The area of the gland ring is less than the area of the inner washer by the sum of the areas of the dowel holes. Thus, in operation, the total force imposed on the annular area of the inner washer is transmitted axially to the reduced area of the gland ring. Consequently, the pressure in the gland ring will always be greater than the pressure in the confined liquid. Gauze washers are inter-

posed between the inner washer and the gland ring to prevent a pressure lock. Chamfered metal rings surrounding the dowels and the piston rod and located between the gland ring and the outer washer prevent outward extrusion of the gland material.

In application, the liquid spring is readily adaptable to almost any form of landing-gear construction. Because of its compactness, it is particularly well suited to articulated or levered suspension types. Figures 4 and 5 show such an installation, in this case a power-steered nose wheel leg. The wheel axle is carried at the end of a lever which is hinged to a pivot bracket. The pivot bracket rotates in bearings within the main fitting. The liquid-spring shock absorber is pin-jointed at one end to the pivot bracket and at the other end to a point on the lever. In this manner the shock absorber is subjected only to axial forces, bending loads being taken by the purely structural portion of the leg. Drag loads are also reacted axially and taken by the shock absorber.

This system is especially advantageous where only limited ground clearance is available. The minimum length of a conventional telescopic leg must be at least twice the stroke plus the necessary overlap required for proper bearing. Using a liquid spring, an articulated leg can provide the same wheel displacement, dissipate the same amount of energy and yet have a

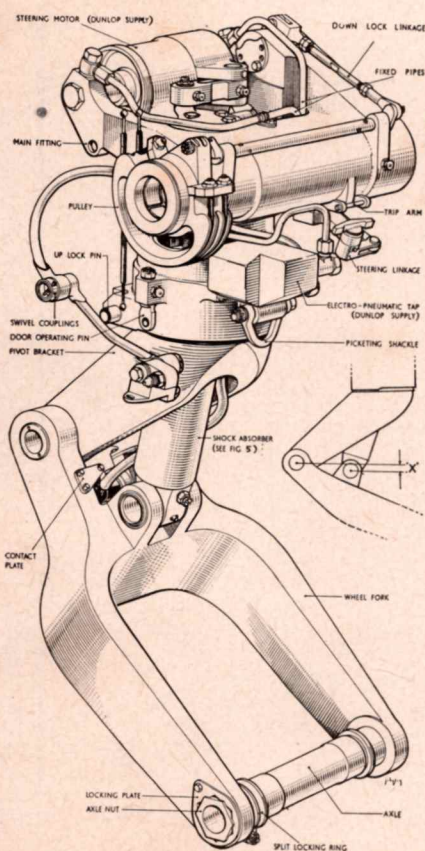


Figure 4—Nose undercarriage.

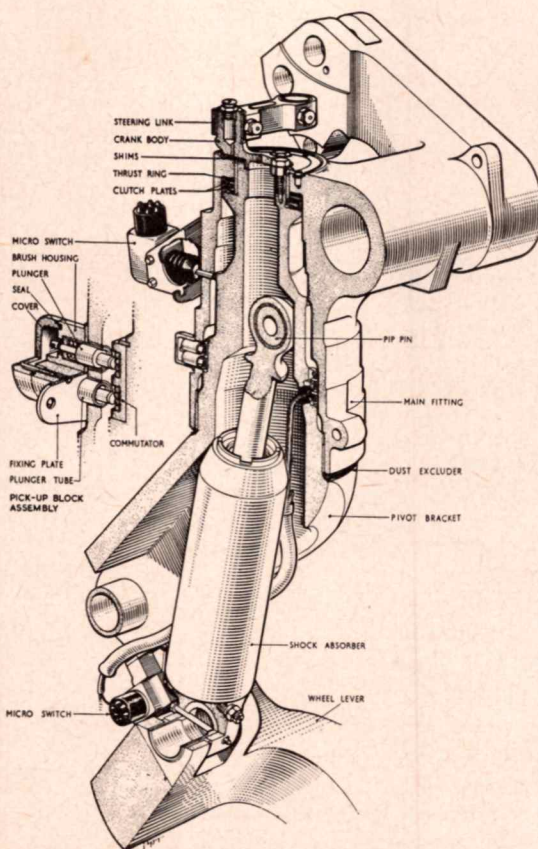


Figure 5—Nose undercarriage cutaway.

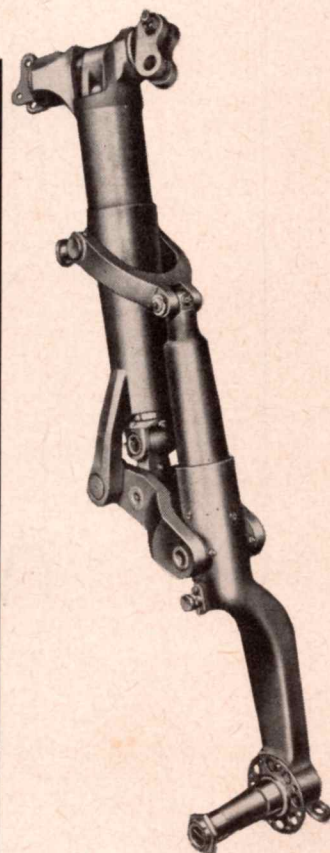


Figure 6—Levered suspension, main landing gear.

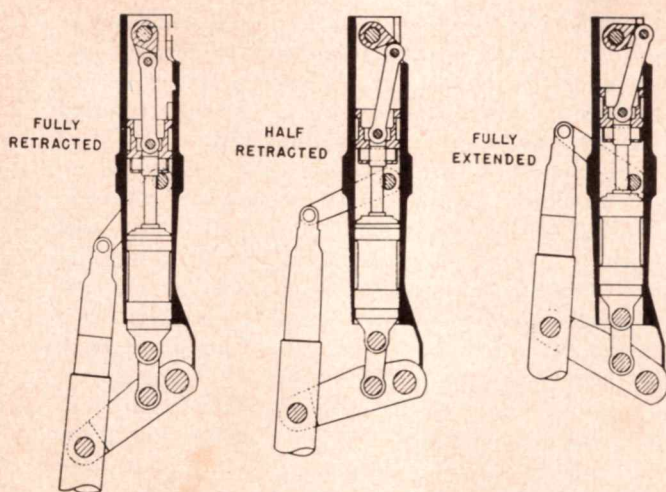


Figure 7—Leg shortening sequence.

piston stroke less than the wheel travel. Because of the high pressures involved, the ratio of cylinder volume to piston rod cross-section (and hence displacement) is a determining factor in the shock absorber's functional characteristics. It is not difficult, by slightly varying this ratio, to design a liquid spring that will

operate at an increased rate on a shorter stroke and still dissipate the required energy without greatly affecting overall size and weight.

● ● Levered Suspension System

An application of the levered suspension principle is shown in Figure 6. This main landing gear arrangement solved two difficult installation problems. The required location of the mainwheels, in relation to the airframe attachment point, resulted in an excessive forward rake which precluded the use of a telescopic leg. The second problem called for foreshortening the landing gear on retraction to fit a limited storage space. As the leg retracts, rotating about a fixed eccentric pin, the shock absorber is pulled up, shortening the leg, Figure 7.

Perhaps the most interesting contemporary designs are those of the bogie type. Evolution of the bogie leg is a direct result of high runway loading factors. For large modern aircraft to use existing runways, it became necessary to distribute the ever-increasing weights over a greater ground contact area. This was initially accomplished by increasing the wheel and tire sizes. However, the obvious limitations to this method

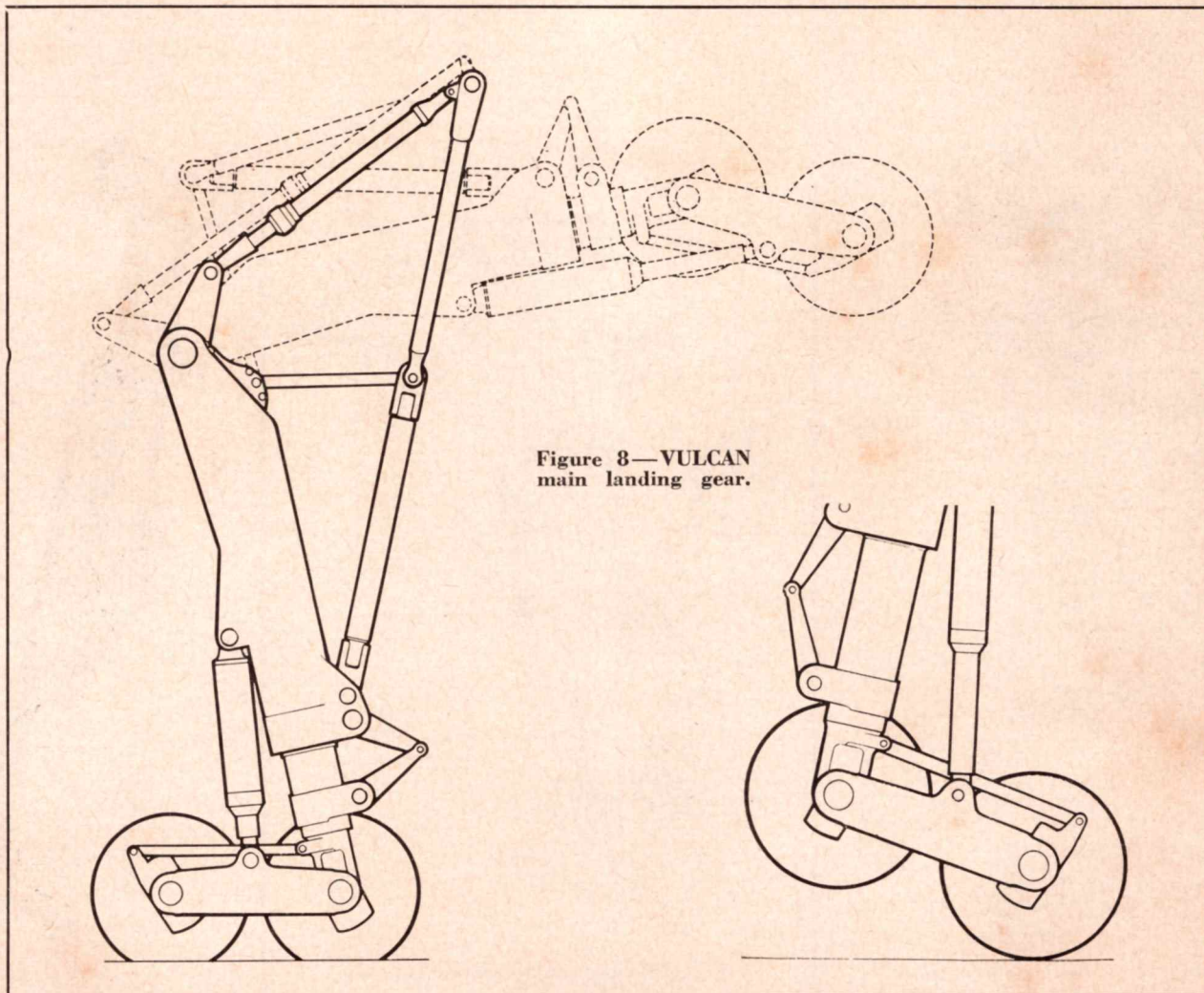


Figure 8—VULCAN main landing gear.

were soon apparent and designers turned to multi-wheeled arrangements.

While the primary function of a bogie design was one of weight distribution, many other advantages were realized. It was found that considerable weight is saved in using several small wheels instead of a comparable single wheel. Also, through articulation great flexibility is available in solving retraction and stowage geometry problems.

The bogie leg shown in Figure 8 is noteworthy for its simplicity. Designed for the Avro *Vulcan* delta-winged bomber, two of these units complete with wheels, brakes and tires, plus a power-steered nose-wheel leg, account for only 3.65 percent of the aircraft's all-up weight.

A single liquid-spring shock absorber is pin-jointed between the main casting and the center of the bogie beam. The tube emerging from the bottom of the main casting is a free sliding member with its downward travel limited by stops and has no upward axial resistance. When extended for landing, the sliding tube is pulled out to its stop by the weight of the bogie beam and wheels. The unloaded shock absorber is fully extended, causing the beam to be carried in a trailing attitude. On touchdown, the total spin-up drag is thereby reduced by taking it in two stages. At the same time, slamming of the front wheels is eliminated by the geometry of the layout. On initial touchdown, the rear wheels contact first and attempt to rotate the beam about the front axle. This

rotation is prevented by a sliding tube travel stop, resulting in the initial load being taken directly by the shock absorber in a manner similar to the simple levered suspension unit described earlier.

The undercarriage is retracted by a single jack, which extends against an integral arm at the top of the main casting. During retraction a single stroke jack, contained in the main member, shortens the leg by drawing the sliding tube into the main casting. This shortening of the leg coupled with the extension of the unloaded shock absorber, rotates the beam to the horizontal stowage position shown in Figure 8.

The simplicity of the leg is achieved by using the liquid-spring shock absorber to perform the work of an anti-pitching damper and a trimming jack in addition to its main function of energy absorption. It also eliminates complicated linkages associated with auxiliary dampers and foreshortening devices.

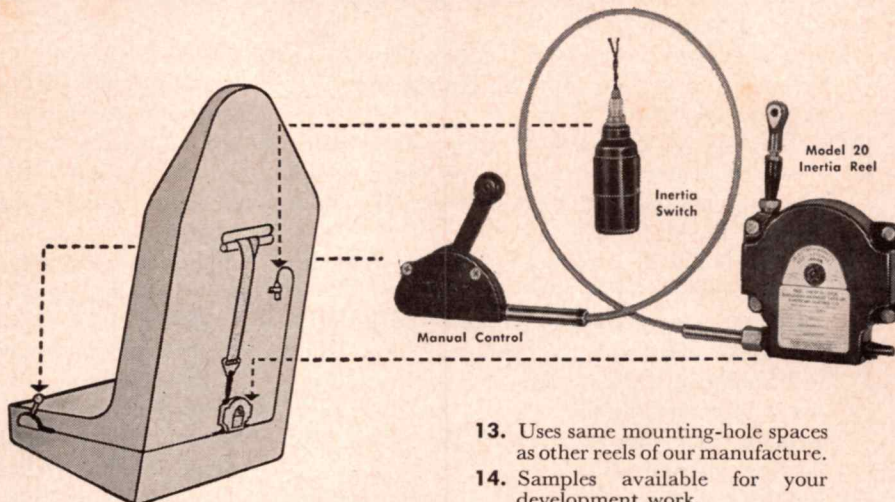
The ultimate in landing-gear design, from the aircraft designer's point of view, is its elimination. Much research has been undertaken in investigating substitute methods for performing the landing gear's vital functions. The landing skid and jettisonable take-off trolley and the flexible deck have met with some success in military applications. However with passenger comfort a prime requisite, it is unlikely that civil aircraft will ever radically depart from the wheel system until vertical take-off aircraft reach the stage of development and adoption where landing and take-off runways are no longer necessary. **END**

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Design Recommendations for

AIRCRAFT INSTRUMENT LIGHTING

A. M. BLUMENFELD

Head of Plastics Design Laboratory
Rohm & Haas Co.
Philadelphia, Pennsylvania

Through use of the unique optical and light-control properties of Plexiglas acrylic plastic, the instrument designer may solve many of his lighting problems. Two general schemes are considered: lighting through the cover glass and lighting from behind the cover glass.

WITH A SOUND KNOWLEDGE of the behavior of light in Plexiglas, the instrument designer should be able to develop means to meet the diversified requirements of aircraft instrument design.

An effective aircraft instrument lighting system should meet the following general requirements:

- 1) Daytime legibility of the instruments must not be hampered by the system.
- 2) Night vision of the pilot must be unimpaired by the system.
- 3) The light sources must create no reflections on the cover glass that are disturbing to the pilot or pilots' positions.
- 4) Reflections on the cockpit glazing areas when viewed from the normal pilots' positions should be minimum and only from indicia and pointer glow, if at all.
- 5) Lamps should be readily accessible in flight for replacement.
- 6) Illumination of markings, pointers and so forth, should be reasonably uniform and controllable in brightness, without glare, and with provision for minimum illumination of the dial backgrounds and panel to avoid the illusion of floating instruments.
- 7) Lighting equipment must not impede visibility of the instrument faces throughout normal viewing angles.
- 8) Little or no usable space should be required to provide for lighting components.
- 9) Instruments should be hermetically sealable as required.
- 10) Instruments should be front-accessible on the panel for replacement.
- 11) Two or more sources of light per instrument must be provided as a safety factor.

- 12) Any acceptable system must satisfy military as well as commercial pilots by departing as little as possible from present visual patterns.
- 13) Instrument lighting must be considered as an integral part of instrument design rather than an afterthought.

● ● Present Lighting Systems

None of the present instrument lighting systems can be considered entirely satisfactory. The use of ultraviolet-activated phosphorescent markings results in eye fatigue, floating instruments and ultimately may cause fluorescing of portions of the human eye. The use of red light in the range of 620 millimicrons or longer (or a 20 to 1 cone to rod ratio) seems to do a better job, but instruments designed for the UV system do not fully adapt to red lighting as well as dial faces especially designed for that purpose. Attempts at individual flood lighting of each instrument have led to the development of 80 or more variations to meet all conditions.

Edge lighting of transparent plastic panels has worked out well for control panels and consoles and though still open to refinement possibilities, would be an excellent starting point for dial faces, if:

- 1) A means could be found to get externally accessible lamps to cast light into a hermetically sealed case without obstructing, reflecting, or taking up usable space.
- 2) Lamps could be sealed into the case with a hope of achieving longevity at the sacrifice of accessibility and the problem of heat dissipation could be reconciled.

Since the plastics commonly used for such applications do not constitute hermetical barriers, they cannot be used as edge-lighted transparent dial covers simi-

lar to those on automobiles and electrical appliances. This does not eliminate their possible use in laminate form, or as separate elements set immediately behind a cover glass with the indicators located behind them.

● ● Behavior of Light Rays

Light rays can enter a transparent material through any angle from 0° (normal to the surface) to $89^\circ 59'$ or nearly parallel to the plane, polished air-interface (dry, uncoated, scratch-free surface intimately in contact with air). At incident angles greater than 60° , however, reflectance losses become wasteful.

Light rays can emerge from a transparent acrylic plastic only when they strike the inside of a plane, polished, air-interface at angles less than 42.2° from the normal.

When both surfaces are optically parallel planes and the polished edge is located at right angles to those surfaces, no light entering through the edge can emerge through either of the optically parallel planes except where a portion of either plane surface is purposely incised, frosted, or painted as numerals, letters or scale markings. Such markings are more efficient and durable when applied to the second surface, the plane opposite the one first being viewed through.

This edge-lighting phenomenon occurs because the maximum incident ray (ray in air) of $89^\circ 59'$ can refract in the transparent acrylic no more than 42.2° from the normal. When this refracted ray falls on the inner surface of the air-acrylic interface of the plane 90° adjacent to the entering interface, it can never strike it at less than 47.8° from the normal to that surface and this is not a small enough angle to permit the ray to emerge; thus it has no alternative but to internally reflect—strike the opposite parallel interface at a like angle and continue across the sheet of clear acrylic plastic and emerge on the opposite edge unless otherwise directed by design.

By painting this opposite edge an opaque light color, the light is prevented from emerging into air and is rebounded back across the plastic sheet to function again where required and to help give uniformity to the brightness level of indicia glow. Prismatic facets and lensic segments integrally designed can be used to direct portions of the light flux to specific areas within and adjacent to the edge-lighted components.

When light falls on unpolished or light colored painted areas, it is scattered diffusely. This is true also of light passing through translucent materials. On the other hand, when light falls upon dark painted or opaque materials it is absorbed in varying degrees depending upon color value and surface finish. Optically parallel surfaces intended for use in edge lighting or light piping should, therefore, never be extensively coated with either light or dark colored paint, because each act to prevent light from traveling efficiently across the part being used. This, incidentally, is the main reason that the present MIL-P-7788 type of edge lighted console panel requires so many lamps per square foot.

● ● Adaptation of Acrylic Plastic

Rohm & Haas experiments are based on two approaches:

Scheme 1—Lamps mounted integrally in the upper corners of the instrument case flange and lighting through the cover glass, Figure 1.

Scheme 2—An edge-lighted sandwich panel with the instrument deriving light from the panel flux by entry through the instrument case at points behind the cover glass, Figure 2.

Each scheme in mock-up form:

- 1) Eliminates cover-glass external reflections from the light sources throughout normal viewing angles of pilot and co-pilot.
- 2) Exceeds the minimum requirements of viewing angle specified by the air services.
- 3) Requires no change in present instrument spacing and uses no otherwise required panel space.

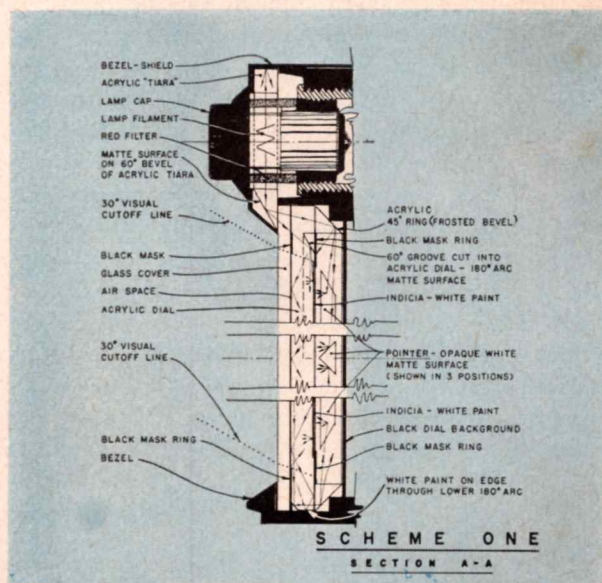
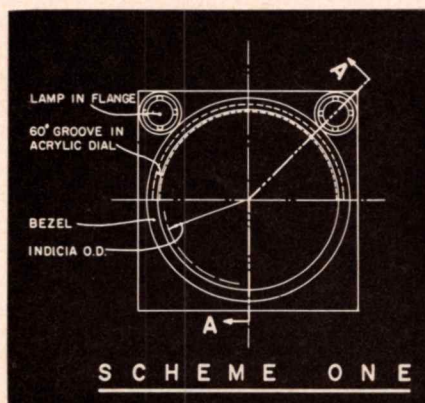


Figure 1—Lighting through the cover glass.

Aircraft Lighting

- 4) Provides good uniformity of indicia brightness and operates well with only one lamp.
- 5) Can be adapted to both flat dials and "deep" instruments such as ball gyros, turn and slip indicators, and counter drums.
- 6) Uses standard console panel edge lighting lamps (with red filters).

In Scheme 1, two lamps are mounted in the upper corners of the flange of a case similar to a standard 3-inch diameter altimeter case.

In front of the flange is a piece of clear acrylic sheet 0.125 inches thick, shaped somewhat like a tiara. The top and sides are square and follow the outer silhouette of the square flange; the lower edge is curved to a half circle following the cover glass bezel line and extending over the glass as far as the bezel that it replaces. Two holes are located concentric with the lamps and permit the lamp filaments to lie in the mean plane of the acrylic sheet. The three flat outer edges are painted white to prevent the escape of usable light by diffuse reflection back toward the bezel curve edge.

At the bezel arc a bevel of 60° from the perpendicular is cut into the sheet and left with an unpolished, finely machined surface. The 60° angle was chosen in preference to the usual 45° to reduce obstruction to vision. The unpolished surface permits slight axial scattering of the rays back through the cover glass.

The tiara is covered by a thin layer of stamped sheet metal which protects the plastic, shields the stray light and preserves a clean air interface on the plastic. The metal touches against the cover glass and prevents any light from reflecting on it.

All of this is achieved within peripheral dimensions of standard flange mounted instruments and provides not only the 30° conical frustum viewing angle required, but nearly 60° without reducing the diameter of the indicia layout.

The rays leaving the tiara pass through the hermetic seal of the cover glass and enter the acrylic dial immediately behind it. A 60° cut on the second surface of the dial disc extends in a half circle that corresponds to the arc of the tiara in order to edge light the indicia on the second surface of the acrylic disc. The lower edge of the acrylic disc is painted white through 180° to reflect internally the rays that would be lost out the bottom of the disc. Above the 60° beveled arc cut in the disc, some of the light from the tiara bevel is allowed to pass through and into a ring with a 45° cut on the second surface. This throws light downward as a side floodlight of 180° in the plane of the pointer (which lies behind the acrylic dial to reduce parallax error).

White paint on the 45° bevel of the lower front of the dial provides a prismatic bleed of light that im-

proves the pointer lighting in the 5 to 7 o'clock area. The pointer is opaque white with a matte surface or knurling to give maximum reflectance to side flood-lighting and is bevelled at 30° to 45°. It should be noted, however, that additional work may be required to improve pointer illumination in this lower area. Thin masking shims are used between the glass and the plastic disc and behind the disc as required to eliminate slight light leakage occurring near the bezel area.

The only dimensional change in instrument case design is the one from the dial background to the outside of the cover glass and this increase of about 0.187 inches to 0.250 inches occurs without resulting in a "deep well" dial effect as in the false panel system.

Variations on this method may range all the way from deep case designs for gyros to counter illumination, and include such possibilities as MIL-P-7788 dial faces located behind the pointer.

Side flooding of the pointer leads to problems of eliminating reflections off the black dial background plate when viewed at angles of 70° or more from the normal. While this is no problem in solo or tandem cockpits, it can be disturbing in side-by-side multiplace cockpits. The most obvious answer seems to be to spin deep concentric serrations into the black dial background which will break up the reflective matte black surface even more, while leaving a minimum background glow to offset the floating indicia phenomenon.

● ● Lighting behind Cover Glass

In Scheme 2, the instrument panel board itself becomes the light source but unlike the MIL-P-7788 principle, the efficiency is markedly improved by preservation of air interfaces on both optically parallel plane surfaces. There are no laminations of white layers to reduce the lateral transmitting efficiency. Instead, a layer of sheet metal is placed in front with a coat of a durable matte-finish black paint.

Behind the light conducting panel of 0.187 inch clear acrylic sheet is a panel of 0.125 inch aluminum with holes aligned with the holes in the acrylic panel and front metal panel. This rear metal panel is the mounting panel for lamp fixtures and instrument cases. Neither of the metal panels need be continuous but may be fabricated in modular segments to permit modification of portions of the panel or the addition of warning messages in little plaques of MIL-P-7788 type copy.

The principal feature of Scheme 2, whether lighted from the panel or from a small integral square bezel appendage, is that all light for the instrument enters the case behind the cover glass.

The lamps are located at the intersections of a grid of imaginary horizontal and vertical lines which pass between adjacent instrument bezels. Thus each lamp can cast its light toward as many as four immediately adjacent instruments if necessary.

The outer edges of the acrylic panel are painted white for return of escaping light rays and help preserve a stray ray light flux that serves as an emergency feature if several of the lamps on the panel fail at once.

Light leaves the panel only through the polished holes cut slightly oversize at the instrument mounting

locations (acrylic plastics expand and contract as much as 1/16 inch per foot due to temperature and humidity changes in a range of about -60°F to $+185^{\circ}\text{F}$ and thus must be allowed for in relation to the adjacent metal mounting and shielding panels).

The instrument case for Scheme 2 resembles a typical clamp-mounted model except that immediately behind the cover glass there is a $\frac{1}{4}$ inch piece of glass tubing whose outside diameter corresponds to the o.d. of the cover glass. The wall thickness of this tubing should be minimum and no more than 0.100 inch.

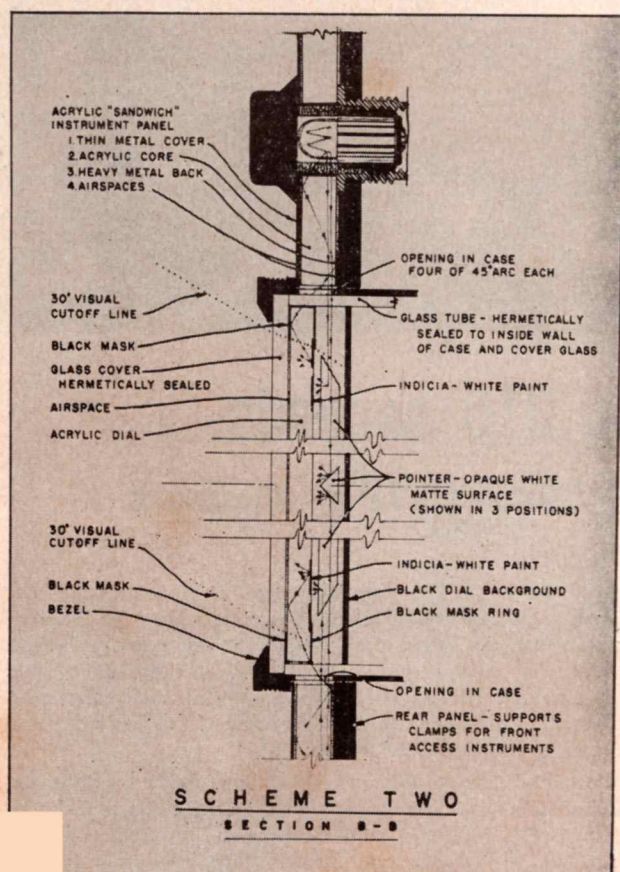
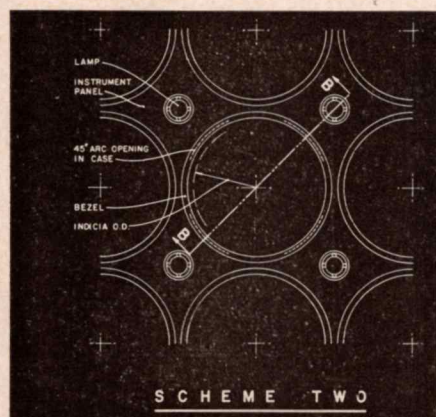


Figure 2—Lighting from behind the cover glass.

Where this tubing abutts against the cover glass and an internal shoulder of the metal case, the edges need not be polished since hermetical seals take place by soldering or epoxy sealants.

The metal case extends forward sleeve-like outside this glass ring and joins the metal bezel of the cover glass. Holes are cut in this metal sleeve in four alternating octant arcs of the circumference. These holes in the metal are not quite as wide as the glass ring ($\frac{1}{4}$ inch) and in length about $1\frac{3}{16}$ inch each.

Since direct rays from the lamps can leave the acrylic panel at the instrument holes only in an octant arc, due to internal reflectance beyond 42.2° from a line normal to the tangent, these holes in the instrument case correspond to the only usable ray emission area of the panel leaving four metal webs between the holes for retention of the cover glass and bezel under internal pressurization at high altitudes.

The light entering the instrument case through the $\frac{1}{4}$ inch wide glass ring can then be used in any number of ways. However, caution should be advised since some rays of light could leave the inner surface of the glass ring at wide enough angles to penetrate the cover glass unless adequate internal shielding is provided. This problem is most acute from light entering from the lower left and right arcs. Light entering from the upper arcs is of no concern in solo or tandem cockpits and less bothersome in side-by-side seating than Scheme 1. For this reason it seems advisable to use only the upper arcs for most instruments and include the lower arcs only for gyros or instruments requiring one of several adjustment controls to be irrevocably mounted in one of the top corners.

● ● Lighting Technique

While there is reason to believe that existing instrument dials (even altimeters which include open windows in the face for adjustment settings) can be adequately lighted by this method of side flooding, let us describe the technique employed in the experimental mock-up. As in Scheme 1, the dial is 0.125 inch thick clear acrylic sheet set immediately behind the cover glass with indicia on the second surface. Since light can enter this dial disc only at four octant arcs, the edge portions corresponding to the metal web of this case sleeve are painted white for internal diffuse reflection. (If only the upper arcs are used for light entry, the entire lower edge is painted white).

Since only half the light coming through the $\frac{1}{4}$ inch wide glass ring enters the dial disc, the remainder can be used as in Scheme 1 to side floodlight the pointers or gyros. Provisions for elimination of wide angle glare from the opaque black painted background are the same as in Scheme 1.

Even with two arcs instead of four, dial illumination is uniform and bright. The use of all four arcs would require considerable dimming of the lamps after dark adaptation of the eye. Pointer illumination is better than in Scheme 1. These studies are only a beginning and may be readily improved and adapted to the specific needs of an infinite number of variations of instrument types and designs.

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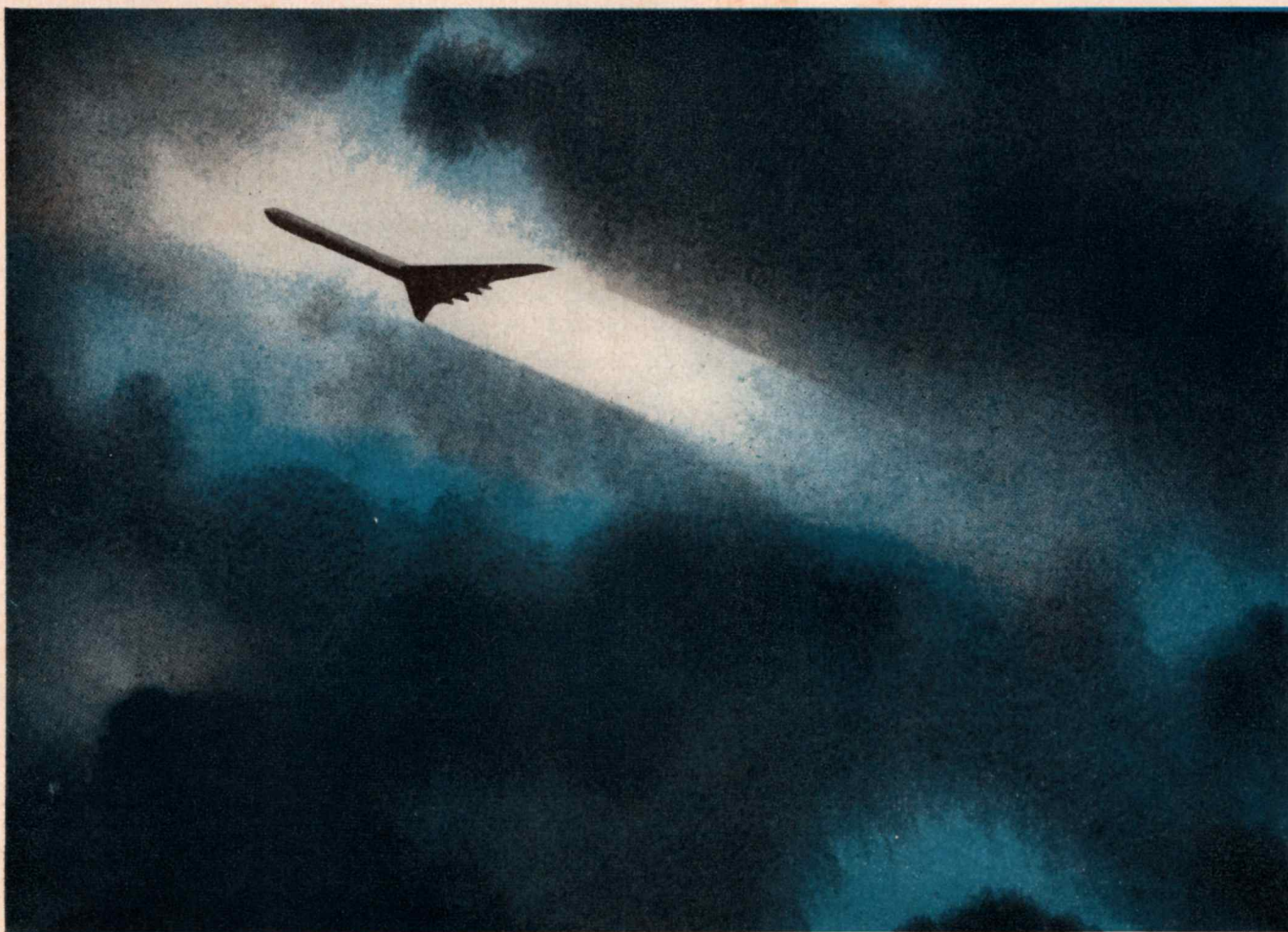
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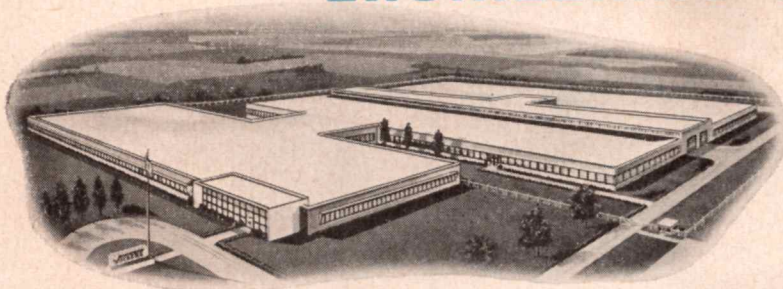
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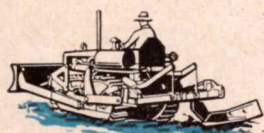


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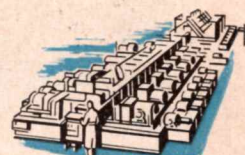
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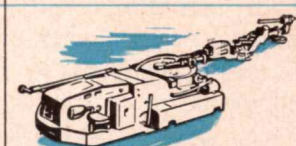
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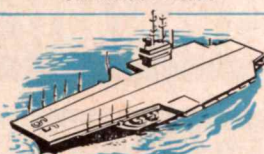
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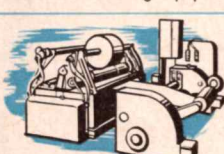
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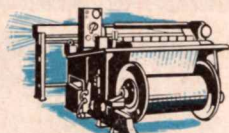
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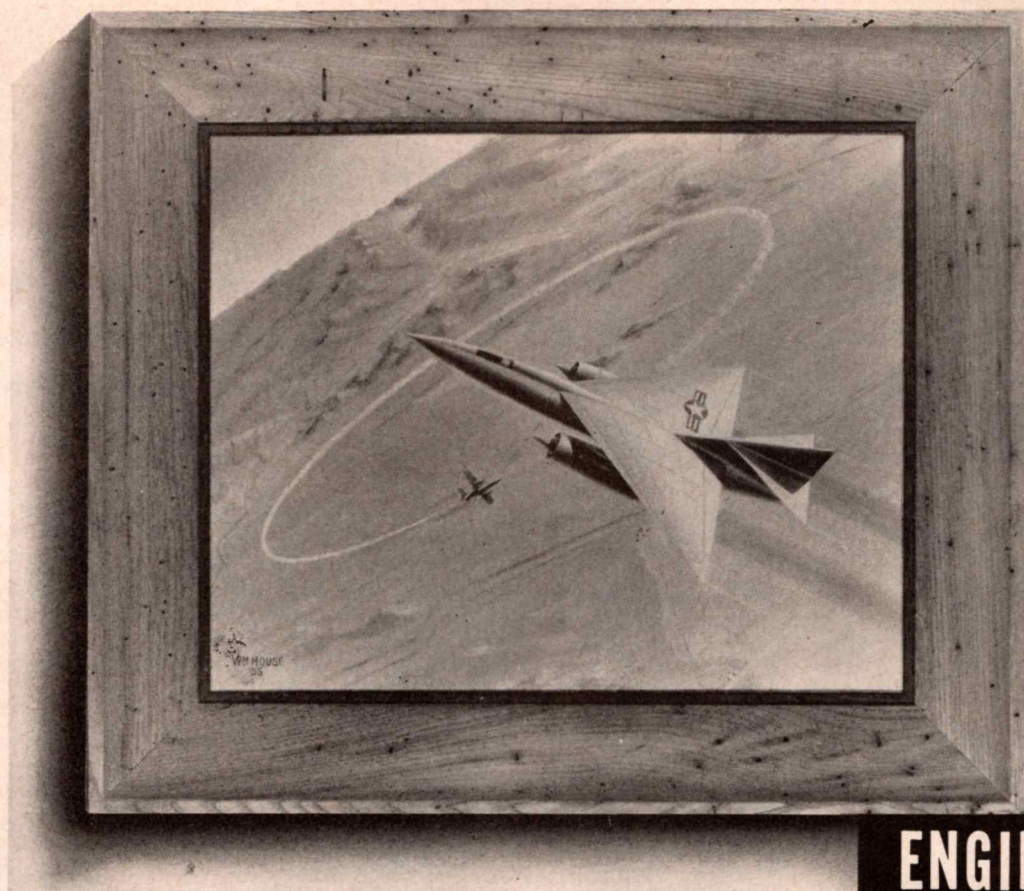
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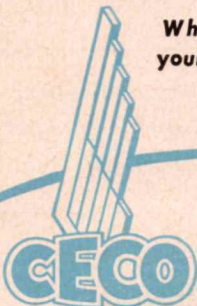
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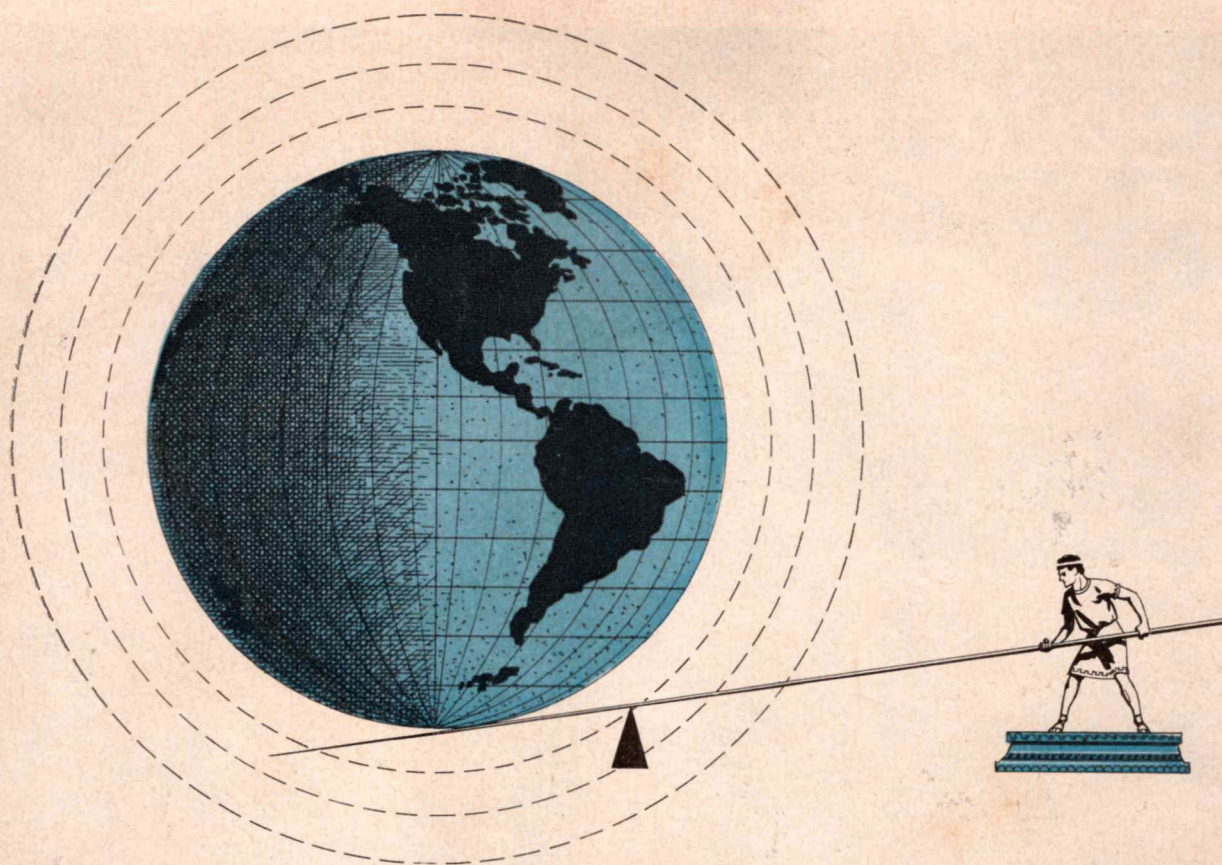


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Archimedes had the right idea

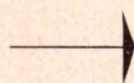
Twenty-one centuries ago Archimedes said . . .
"Give me a place to stand and I will move the world."

His principle works as well today as it did then. You can accomplish more with the same effort if you have the right spot to "stand" and the right job as a fulcrum. For the engineer, that spot and that job are at Temco.

Temco is big enough to offer you scope for your abilities, but not so big that those abilities will be lost in the crowd. Temco is old enough to offer you stability and prestige, young enough so that you can match its dynamic growth stride for stride.

Apply sound principles to your plans for progress, use the right methods to make your native

ability take you further. You can do it at Temco! There are openings at Temco plants in three Texas communities — Dallas, Garland and Greenville.



Write: Engineering Personnel
Temco Aircraft Corporation, Dept. A
P.O. Box 6191, Dallas 2, Texas



AIRCRAFT CORPORATION. DALLAS

AERO DIGEST

LOCKHEED AIRCRAFT CORPORATION
GEORGIA DIVISION
AIR FORCE PLANT NO. 1

12

11

10

**ROUND THE CLOCK...
THROUGHOUT THE YEAR...**

9

8

7

**LOCKHEED IN GEORGIA
MOVES AHEAD**

Here at the world's largest integrated aircraft plant, in Marietta, Georgia—where the Lockheed C-130 Turbo-Prop Cargo planes and B-47 Jet Bombers are built—we welcome two new Lockheed programs to Georgia.

One is our huge new Engineering Center here at the plant and the other is our multi-million dollar nuclear powered aircraft development facility.

Here are projects to challenge the very limits of imagination, vision, ability and capabilities of man!

Qualified Engineers and Scientists interested in becoming associated with this progressive and rapidly expanding organization are invited to inquire for further information or personal interview.

R. I. V. P.
ENGINEERING PROFESSIONAL PLACEMENT
LOCKHEED

AIRCRAFT CORPORATION DEPT. AD-8
761 PEACHTREE N. E., ATLANTA, GEORGIA

Engineering Opportunities For Technically-Trained Men

Manufacturers of aircraft and aircraft equipment were surveyed by AERO DIGEST to learn their current engineering employment needs. Based on company-furnished data, the positions available are classified on the basis of job descriptions, education and experience.

The following tables list the positions open in engineering companies throughout the U.S. AERO DIGEST gained the data through the cooperation of American industry. Trained engineers not working to their full technical capacity on engineering projects connected

with national defense are urged to consider the openings they can fill. For the convenience of these engineers, AERO DIGEST has prepared a standard application blank, called *Aeroform*, which can be obtained by circling 90 on the READER REPLY CARD, page 80A. Indicate on the right margin of the card the number of blanks you wish. These have been prepared and approved for use by leading companies in the aeronautics industry.

AERO DIGEST is continuing its employment service as a semi-annual feature. The next round-up of engineering positions available will appear in the February 1957 issue.

**Table 1—Symbols for
NUMBER YEARS EXPERIENCE IN THE FIELD**

NO. YEARS	SYMBOL
0-3	a
3-5	b
5-10	c
10 and up	d

Table 2—Symbols for JOB DESCRIPTION

AERODYNAMICS	Instrumentation	27	PHYSICS AND MATHEMATICS	
Fixed wing	Servomechanisms and regulating system design	28	Acoustics	57
Rockets and missiles	Telemetering	29	Anti-gravity	58
VTOL and STOL			Solid state studies	59
AIRFRAME DESIGN	HYDRAULICS		NUCLEAR	
Surface and fuselage, furnishings and equipment, design integration	Design, systems evaluation, transmission and test	30	(Design of all phases of power-producing reactor systems in the following fields)	
ARMAMENT	HYDRODYNAMICS		Controls analysis	60
Fire control systems, rocket launchers, aerial cannon and associated equipment	Hydrodynamic analysis and test	31	Element problems	61
Missile and weapons control systems studies	INSTRUMENTATION		Heat transfer	62
Solid propellant rockets and explosive devices	(Systems evaluation, design, installation and test).		Instrumentation	63
DETAIL DESIGN	Autopilots	32	Metallurgical corrosion and material problem	64
Drafting and computations	Computer systems	33	Metallurgical fuel	65
DYNAMICS	Electromechanics	34	Nuclear analysis	66
Field and wind tunnel testing	Flight test	35	PROJECT MANAGEMENT	
Load and vibration analyses	Gages and indicators	36	(Responsible direction of major projects)	
ELECTRICAL	Gyros	37	Aircraft	67
Electrical power systems for aircraft and missiles; this includes installation and circuit design of generating, distribution and utilization systems	Navigation	38	Electronics	68
ELECTRONICS	Packaging and installation	39	Missiles	69
(System evaluation, design, installation and test.)	Programming	40	PROPULSION	
Antennas	Servomechanisms and regulating system design	41	(Performance prediction, preliminary and final design, installation and test.)	
Circuitry	Systems engineering	42	Aero-thermodynamics	70
Components	Test and service	43	Auxiliary power systems	71
Computers	LIAISON		Fuels and oxidants	72
Infrared	Customer contacting, selling and servicing including engineering proposals and contracts	44	Heat transfer	73
Magnetic Amplifiers	MATERIAL AND METHODS		Internal combustion engines	74
Pulse	Engineering	45	Jet engines	75
Radar	Metallurgy	46	Rocket and missile powerplants and boosters	76
Radomes	Production	47	STRUCTURES	
Receivers	Liaison between manufacturing and tooling including jigs and fixtures...	48	Aeroelasticity including flutter	77
Sonar	MECHANICAL		Static and dynamic test	78
Test and service	Air conditioning and heat exchange ..	49	Stress and structural analysis	79
Transistors	Auxiliary power equipment	50	TECHNICAL WRITING	
GUIDANCE	Control systems and landing gears ..	51	Writing and editing engineering reports and proposals	80
Computer systems	Design layouts	52	WEIGHTS	
Guidance systems analysis	Launching equipment design	53	Solving weight and balance problems on aircraft and missiles	81
	Mechanisms	54		
	Pneumatic systems and components ..	55		
	Turbine and compressor design	56		

KEY TO LISTINGS

In the Positions Available list, engineering opportunities are related to Number Years Experience in the Field (Table 1) and Job Description (Table 2).

For example, if you have an electrical engineering degree, and have worked in the Guidance field where you have had 3 to 5 years Experience with Computer Systems, then look under the category Electrical Engineering Degree Preferred for the symbol 25B.

POSITIONS AVAILABLE

Aeronautical Engineering Degree Preferred

AEROJET-GENERAL
2ab, 10ab, 70ab, 77ab, 79ab

AERO SUPPLY MFG.
8c

AIRCRAFT ENG. & MAINTENANCE
44a, 8a, 19a, 45b, 47b

ALL AMERICAN ENGINEERING
79b

ALLISON DIV.—G.M.C.
35bc, 56bcd, 70bcd, 75bcd, 77bcd

ANDERSON, GREENWOOD & CO.
2abcd, 4ab, 8a, 70ab, 80a

AUTONETICS DIV. & MISSILE DEVEL. ENG.—NORTH AMERICAN
1abcd, 2abcd, 4abcd, 9abcd, 10abcd, 60a, 70abc, 76abc, 77abcd, 78abcd, 79abcd

AVCO MFG.—ADVANCED DEVELOPMENT DIV.
1b, 9b, 70b, 78b

AVRO AIRCRAFT
1abc, 4b, 10b, 79ab, 80bc

BELL AIRCRAFT (BUFFALO)
1b, 2b, 3b, 70bc, 73b, 76b

BELL AIRCRAFT—FT. WORTH
3ab

BENDIX PRODUCTS DIV., MISSILES (INDIANA)
2bcd, 10bcd, 81bc

BOEING AIRPLANE
1abcd, 2abcd, 8abcd, 9abcd, 44ab, 45abcd, 47abcd, 48abcd, 80abcd

BROOKS & PERKINS
4a, 5a, 8a-10a, 12a, 14a, 15a, 20a, 21a, 23a, 31a, 39a, 44a, 73a, 77a-79a

BURTON RODGERS—TECH. TRG.
4b, 80ab

CAMBRIDGE CORP.
8b, 79b

CANADAIR
1abc, 2abc

CHANCE VOUGHT ACFT.
1bcd, 4abc, 9b, 10ab, 35ab, 67c, 69c, 70bc, 73bc, 75ab, 76bc, 77b, 79abc, 80b, 81abc

CLARY CORP.
30abcd

CLEVELAND PNEUMATIC TOOL
8a, 30ab, 51bc, 52b, 54bc, 79abc

CONTINENTAL AV. & ENG.
2b, 10ab, 14ab, 23ab, 28b, 34bc, 41abc, 52abc, 54b, 55b, 56abc, 70bc, 73b, 74abc, 75abc, 76b, 78b, 79b, 80a, 81a

CONVAIR—FT. WORTH
1abcd, 4abcd, 6abcd, 8abcd-10abcd, 70abcd, 77abcd-79abcd

CORNELL AERO. LAB.
1bd, 2bc, 6bd, 67cd, 69cd, 70bd, 73bd, 75bd

COX & CO.
8a

CURTISS WRIGHT—ELEC. DIV.
4c, 35b, 74b, 75b

DOMAN HELICOPTERS
4c, 79c

ERCO DIV., ACF IND.
9a, 40ab

FAIRCHILD AIRCRAFT DIV.
1abc, 2bc, 3c, 8b, 10c, 45b, 69c, 75c, 77c, 80b, 81b

FAIRCHILD ENG. DIV.
1b, 9b, 52ab, 56bcd, 70bcd, 75abcd, 78bcd, 79bcd

FAIRCHILD GUIDED MISSILES DIV.
1abcd, 2abcd, 4abcd, 6abcd, 8abcd-10abcd, 25abcd-29abcd, 32abcd-43abcd, 45abcd-48abcd, 67cd, 69cd, 70abcd, 77abcd-79abcd, 80abcd, 81abcd

FAIRCHILD ELECTROTECHNICS
4b, 62b, 70b-73b, 79c, 80b

GE-ACFT. GAS TURBINE DIV. (CINCINNATI, OHIO)
2ab, 3ab, 7ab, 9abc, 10abc, 35ab, 44abcd, 54ab, 56ab, 70ab, 74ab, 75ab, 76abc

GENERAL ELECTRIC (SCHENECTADY)
2bcd, 5bcd-8bcd, 10bcd, 11bcd-30bcd, 32bcd-43bcd, 46bcd-52bcd, 54bcd-56bcd, 60bcd-66bcd, 68bcd-81bcd

GENERAL MILLS (MECH. DIV.)
2abcd, 9abcd, 10abcd, 70abcd, 71abcd, 77abcd, 78abcd, 79abcd, 81abcd

GRAND CENTRAL ROCKET
2abcd, 7abcd, 8abcd, 10abcd, 30abcd, 69abcd, 70abcd, 76abcd, 79abcd-81abcd

HELIO AIRCRAFT
4b, 8a, 79b

HOFFMAN ELECTRONICS
32abcd-34abcd, 38abcd, 79abcd

KETT CORP.
70b, 71b, 73b, 75b, 79b

LEAR (SANTA MONICA)
4abcd, 8abcd, 10abcd, 67abcd, 79abcd, 80abcd

LOCKHEED AIRCRAFT
1abcd, 5abcd, 9abcd, 10abcd, 62abcd, 70abcd-77abcd

LOCKHEED GEORGIA DIV.
1bcd, 4bcd, 8b, 10bc, 35bc, 45bc, 51cd, 52cd, 54c, 70c, 77cd, 78c, 79c, 80bc, 81c

LOCKHEED (MISSILE SYS. DIV.)
2abcd-10abcd, 30abcd, 32abcd-43abcd, 49abcd-56abcd, 70abcd, 73abcd, 76abcd-81abcd

MCDONNELL AIRCRAFT
1d, 2c, 4a, 5b, 6c, 7c, 8a, 9c, 26b, 35b, 39d, 40b, 45c, 49b-53b, 69d, 77b, 78b, 80b

MARTIN AIRCRAFT—BALTIMORE
1abcd-4abcd, 9abcd, 10abcd, 25abcd-31abcd, 35abcd, 44abcd, 55abcd, 67abcd, 69abcd, 70abcd, 73abcd, 75abcd-81abcd

MELETRON
41a

NEW YORK AIR BRAKE
8ab, 28b, 30abcd

NORTH AMERICAN
1abcd, 2abcd, 9abcd, 10abcd, 70abcd, 75abcd-79abcd, 81abcd

NORTH AMERICAN—COLUMBUS DIV.
1abcd, 2b, 6bc, 9bcd, 10bcd, 70bc, 73bc, 77abcd, 79bc, 81bcd

NORTHROP AIRCRAFT (HAWTHORNE, CALIF.)
1abcd-4abcd, 8abcd-11abcd, 30abcd, 31abcd, 51abcd-53abcd, 55abcd, 70abcd-81abcd

PACIFIC SCIENTIFIC
44abc, 51abc, 54abc

OMAR (OLIN MATHIESON, MARQUARDT AIRCRAFT, REACTION MOTORS)
6bc-8bc, 10bc, 41bc, 44bc, 62bc, 64bc, 70bc, 71bc, 72bc, 76bc, 78bc-80bc

PHEOLL MFG. CO.
4b

PREWITT AIRCRAFT
4cd, 67c, 78b, 79d, 81b

PSC APPLIED RESEARCH
2abcd, 4abcd-6abcd, 9abcd, 11abcd-25abcd, 27abcd-29abcd, 32abcd-44abcd, 67cd-69cd, 80abcd

REACTION MOTORS
70c, 76c, 80bc

REPUBLIC AVIATION (GUIDED MISSILES DIV.)
1abcd, 2abcd, 6abcd, 69cd, 70abcd, 76abcd

ROCKETDYNE—DIV. OF NORTH AMERICAN
2abcd, 8abc, 9abc, 10abcd, 30abc, 31abcd, 49abc-55abc, 56abcd, 60abc-63abc, 70abcd, 71abc, 72abc, 73abcd, 75abcd, 76abcd, 78abc, 79abc, 81abc

RYAN AERONAUTICAL
1a, 2b, 3a, 4ab, 5b, 6b, 10b, 77b-79b, 81bc

SERVOMECHANISMS (HAWTHORNE, CALIF.)
80abcd

TEMCO AIRCRAFT
1b, 4abcd, 9abcd, 10abcd, 32abcd-43abcd, 49abcd-55abcd, 70abcd-76abcd, 77bcd-79bcd, 81bcd

FRANE CO.
8ab, 44ab, 49abc, 62abc

WINZEN RESEARCH
4b, 80b

Chemical Engineering Degree Preferred

AEROJET-GENERAL
7ab, 46ab, 64ab, 65ab, 72ab

AIRCRAFT CONTROLS
63b

ALLISON DIV.—GMC
46bcd, 64cd, 66cd, 72bcd

ATOMIC INTERNATIONAL—DIV. OF NORTH AMERICAN
44bcd, 46abc, 52abc, 59abcd, 60abcd-66abcd, 79bc, 80abc

AVCO MFG.—ADVANCED DEVELOPMENT DIV.
46b, 64b

AVRO AIRCRAFT
46ab

Employment

BAY STATE ABRASIVE
45ab

BENDIX COMPUTER
15abed

BOEING AIRPLANE
45abed, 47abed, 48abed, 62abed, 64abed, 80abed

CEE-BEE CHEMICAL
45ab, 47ab

CHANCE VUGHT ACFT.
46b

CHRYSLER CORP.—ENGINEERING DIV.
46ab

CONVAIR—FT. WORTH
46abed, 64abed, 65abed

CORNELL AERO. LAB.
62bc, 64b

CORNING GLASS
8ab, 44abed

FORD MOTOR—AIRCRAFT ENGINE DIV.
46abc

GE-ACFT. GAS TURBINE DIV.
(CINCINNATI, OHIO)
6ab, 7ab, 46abed, 62ab, 64ab, 72abc, 76ab

GENERAL ELECTRIC (SCHENECTADY)
8bed, 70bed-76bed, 80bed, 81bed

GENERAL MILLS (MECH. DIV.)
70abed-73abed

GRAND CENTRAL ROCKET
7abed, 8abed, 44abed, 46abed, 59abed, 70abed-
73abed, 76abed, 80abed, 81abed

LOCKHEED AIRCRAFT
45abed, 46abed, 64abed, 65abed

LOCKHEED GEORGIA DIV.
46d

LOCKHEED (MISSILE SYS. DIV.)
8abed, 46abed, 60abed-66abed, 80abed, 81abed

MCDONNELL AIRCRAFT
7d

MARTIN AIRCRAFT—BALTIMORE
2abc, 7abc, 46abed, 61abed, 64abed-66abed

MINN. MINING & MFG.
44ab, 67b

NORTH AMERICAN
73 bed

NORTH AMERICAN—COLUMBUS DIV.
70bc, 73bc

NORTHROP AIRCRAFT (HAWTHORNE, CALIF.)
7abed, 46abed, 72abed-76abed

OMAR (OLIN MATHIESON, MARQUARDT AIR-
CRAFT, REACTION MOTORS)
7bc, 44bc, 62bc, 64bc, 66bc, 72bc, 76bc, 80bc

PREWITT AIRCRAFT
4c, 52c

RCA-CAMDEN, N. J.
14ab, 24abc, 59abc

REACTION MOTORS
66c, 80c

ROCKETDYNE—DIV. OF NORTH AMERICAN
2abc, 31abed, 42abc, 43abc, 45abc, 46abc,
49abc, 60abc-63abc, 72abed, 73abed, 74abc,
75abed, 76abed

SUNSTRAND MACH. TOOL (AVIATION DIV.)
46abed

TITFLEX INC.
64b

TRANE CO.
44ab, 49abed, 62abed

UTICA DROP FORGE & TOOL
46a

Civil Engineering Degree Preferred

AEROJET—GENERAL
8ab, 49ab

ANDERSON, GREENWOOD & CO.
8a, 77a, 79abc

ALLISON DIV.—GMC
78abed, 79abed

ATOMIC INTERNATIONAL—DIV. OF
NORTH AMERICAN
44bed, 49abed, 52abc, 80abc

AUTONETICS DIV. OF MISSILE DEVEL. ENG.—
NORTH AMERICAN
78ab, 79a

AVRO AIRCRAFT
79ab

BOEING AIRPLANE
8abed, 30abed, 31abed, 45abed, 47abed, 48abed,
77abed-81abed

CAMBRIDGE CORP.
8b, 79b

CANADAIR
10b, 77b-79b

CHANCE VUGHT ACFT.
4abc, 10abc, 79abc, 80b

CHRYSLER CORP.—ENGINEERING DIV.
79ab

CLEVELAND PNEUMATIC TOOL
79abc

CONVAIR—FT. WORTH
4abed, 8abed, 79abed, 81abed

CORNING GLASS
8ab, 30abed, 44abed

DRESSER—IDECO
8ab, 79ab

FAIRCHILD AIRCRAFT DIV.
79abc

FORD MOTOR—AIRCRAFT ENGINE DIV.
46abc

GE-ACFT. GAS TURBINE DIV. (CINCINNATI)
4ab

GENERAL ELECTRIC (SCHENECTADY)
2bed, 5bed-8bed, 10bed, 26bed-29bed, 32bed,
43bed, 46bed-52bed, 54bed-56bed, 60bed-66bed,
68bed-81bed

GRAND CENTRAL ROCKET
8abed, 10abed, 30abed, 31abed, 69abed, 79abed-
81abed

HARNISCHFEGER
44a

HOFFMAN ELECTRONICS
79abed

LOCKHEED AIRCRAFT
8abed, 78abed, 79abed, 81abed

LOCKHEED—GEORGIA DIV.
4bed, 8b, 10bc, 52cd, 78c, 79c, 80bc, 81c

LOCKHEED (MISSILE SYS. DIV.)
4abed, 8abed-10abed, 30abed, 77abed-81abed

MCDONNELL AIRCRAFT
4d, 8a, 52b, 77b-79b, 81b

MARTIN AIRCRAFT—BALTIMORE
4abed, 64abed-66abed, 77abed-81abed

NORTH AMERICAN
78abed, 79abed, 81abed

NORTH AMERICAN—COLUMBUS DIV.
4abed, 51abed, 77abed, 79bc

NORTHROP AIRCRAFT (HAWTHORNE, CALIF.)
1abed-4abed, 8abed-10abed, 30abed-43abed,
49abed-56abed, 70abed-81abed

REPUBLIC AVIATION (GUIDED MISSILES DIV.)
4abed, 77abed, 79abed, 81abed

ROCKETDYNE—DIV. OF NORTH AMERICAN
8abc, 30abc, 31abed, 73abc, 78abc, 79abed, 81abc

SUNSTRAND MACH. TOOL (AVIATION DIV.)
52abed, 80abed

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and controls
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are now open for aerodynamicists
... mechanical engineers

... mathematicians ... specialists in
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engineers ... electronics engineers.

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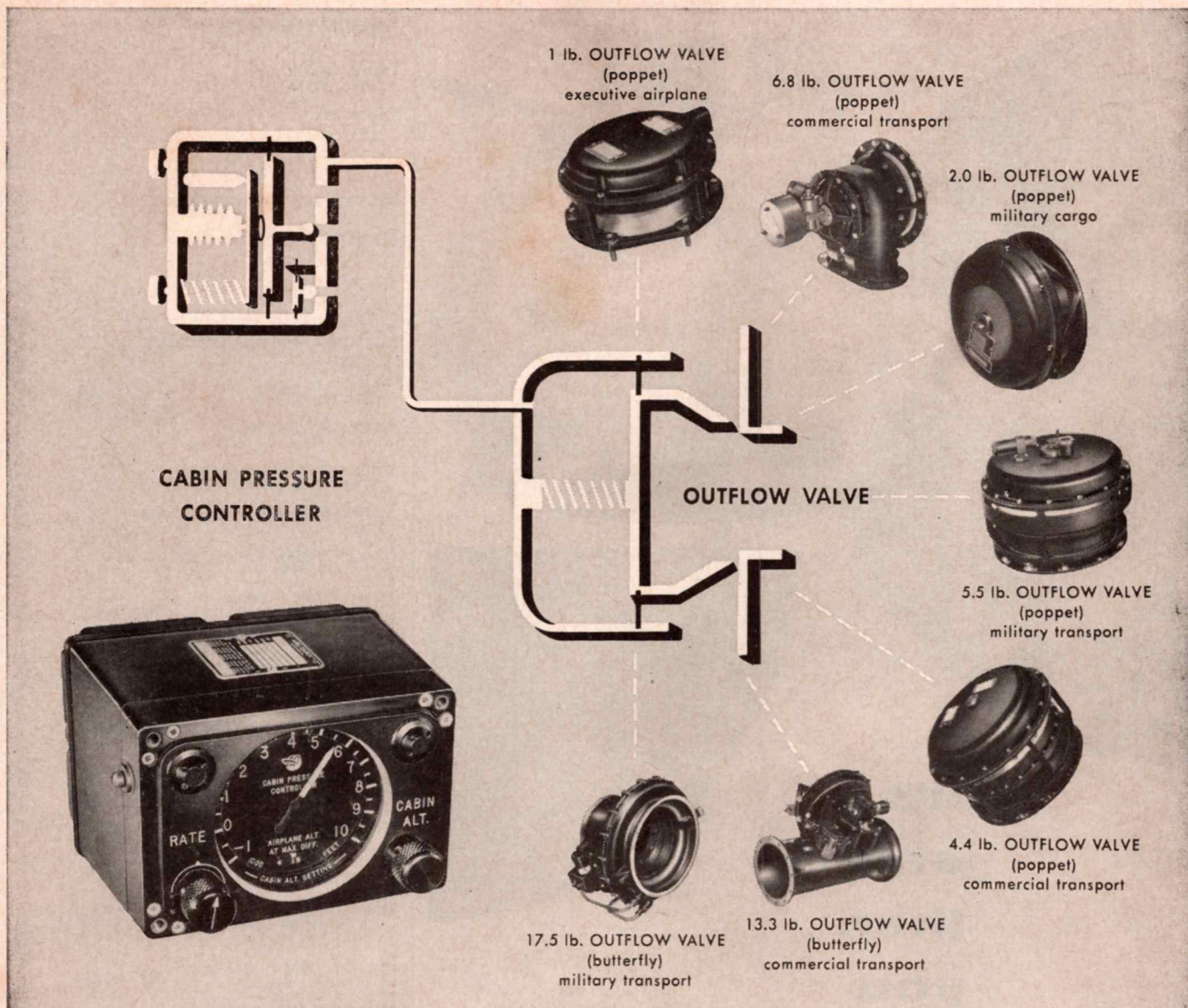


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AiResearch Manufacturing,
Phoenix
AiResearch Industrial
Rex — Aero Engineering
Airsupply — Air Cruisers
AiResearch Aviation
Service

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circle Reader Reply No. 2

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Two unit pressure control

FOR ALL SIZES OF AIRCRAFT CABINS

Simple, proved AiResearch pneumatic system operates independently...requires no outside power

The two elements of the complete AiResearch cabin pressure control system are a pneumatic controller and an associated outflow valve.

Only calibration is required to adapt the controller to various aircraft cabin pressure requirements. Minimum or no servicing is needed.

The outflow valve is a simple diaphragm and spring operated valve connected to the controller by a pneumatic line. It may also serve as a safety valve under emergency conditions.

An electrical or pneumatic override can be provided to give the

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This system is immediately available for all aircraft models. Your inquiry is invited.

Qualified engineers are needed now for unexcelled career opportunities. Write for information.



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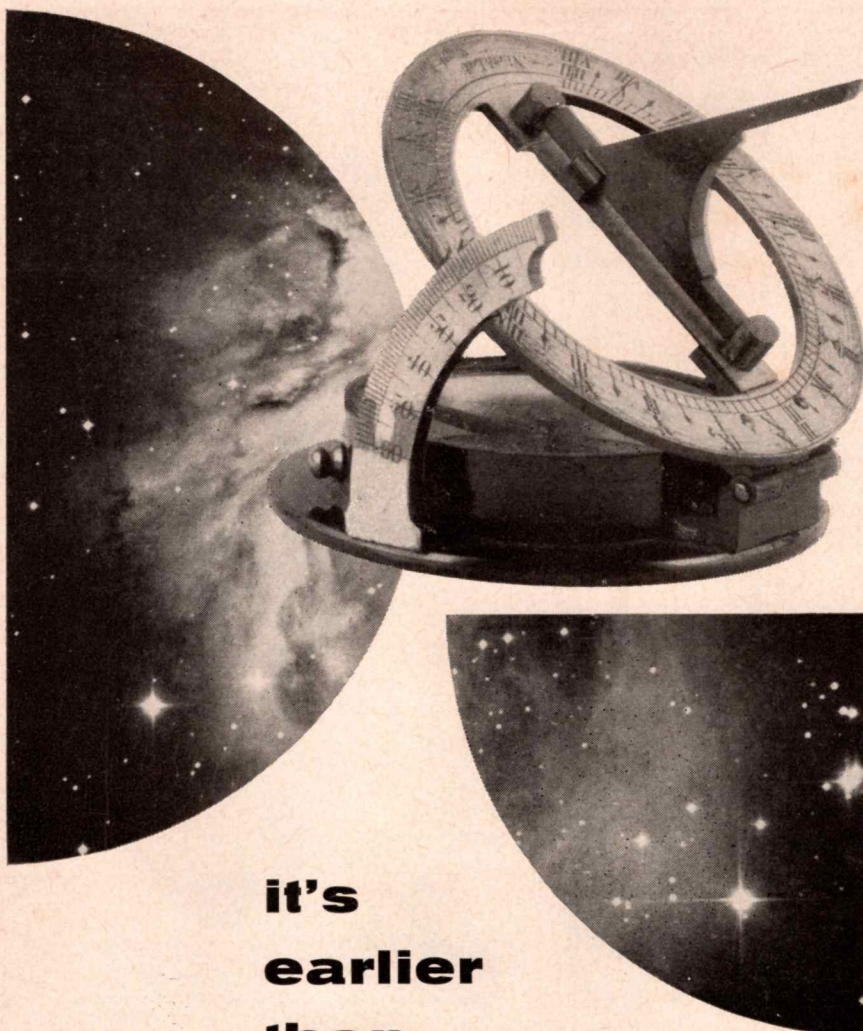
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Designers and manufacturers of aircraft systems and components: REFRIGERATION SYSTEMS • PNEUMATIC VALVES AND CONTROLS • TEMPERATURE CONTROLS
CABIN AIR COMPRESSORS • TURBINE MOTORS • GAS TURBINE ENGINES • CABIN PRESSURE CONTROLS • HEAT TRANSFER EQUIPMENT • ELECTRO-MECHANICAL EQUIPMENT • ELECTRONIC COMPUTERS AND CONTROLS

For further information circle Reader Reply No. 1

AUGUST 1956



**it's
earlier
than
you
think**

An important group of engineers in the aircraft industry is already working on the threshold of outer space.

That group is at Martin, where creative engineering is being applied to research and development in the most advanced areas of rocketry and space systems planning.

No other organization in the world has a higher ceiling on its future.

This is the ground floor, and it's earlier than you think. If you are interested in exploring some of the most exciting engineering opportunities in the world today, contact J. M. Holiday, Dept. AD-08, The Martin Company, Baltimore 3, Maryland.

MARTIN

Employment

TEMCO AIRCRAFT
4bed, 77bed-79bed, 81bed

TRAN CO.
44ab

Electrical Engineering

Degree Preferred

ABRAMS INSTR.
19b, 34bc, 41b

AC SPARK PLUG
12a, 13a, 15a, 19a, 23a, 25a-28a

AEROJET—GENERAL
11ab, 13ab-16ab, 21ab, 23ab, 25ab-27ab, 29ab,
33ab, 34ab, 39ab, 42ab, 43ab, 63ab, 69ab

AIRCRAFT CONTROLS
14abc, 17abc, 27abc, 28abc

AIRCRAFT-MARINE PROD.
14abc, 18abc, 19abc, 59abc

AIRESEARCH MFG. CO. OF ARIZ.
23ab

ALL AMERICAN ENGINEERING
2b, 41b, 43b

ALLISON DIV.—GMC
13abc, 14abc, 15bed, 17bed, 23abcd, 24bed, 33bed,
34bed, 36ab, 41bed, 42bed, 43abcd

ANDERSON, GREENWOOD & CO.
11ab, 39ab, 42abc

ATOMICS INTERNATIONAL—DIV. OF
NORTH AMERICAN
34b, 42b, 44bed, 52abc, 60abcd-66abcd, 79bc,
80abc

AUTONETICS DIV. & MISSILE DEVEL. ENG.—
NORTH AMERICAN
11abcd-29abcd, 32abcd-43abcd, 69cd, 80abc

AVCO MFG.—ADVANCED DEVELOPMENT DIV.
11b-15b, 18b, 23b, 25b, 26b, 29b, 34b

AVRO AIRCRAFT
35bc

BELL AIRCRAFT (BUFFALO)
11ab, 12abc, 13abc, 17ab-19ab, 24ab, 25abc,
26bc, 27bc-29bc, 38b

BELL AIRCRAFT—FT. WORTH
11ab, 24a, 28ab

BENDIX AVIATION (FRIEZ INST. DIV.)
8c, 11bc, 13abcd, 23ab, 28b, 34abc

BENDIX AVIATION—SCINTILLA DIV.
8ab, 11ab, 17ab, 23ab, 34ab, 80ab

BENDIX COMPUTER
15abcd

BENDIX PROD. DIV., MISSILES (INDIANA)
6bc, 11bed, 12bc-15bc, 17bc-19bc, 25bc, 26bed,
27bc, 28bed, 33bc, 34bc, 41bc, 42bc, 69bc, 80bc

BENDIX RADIO DIV., BENDIX AVIATION
12b, 13bc, 14b, 18b, 19bc, 21b, 24b, 25b, 26bc,
27b, 28bc, 34bc, 38bc, 40b, 41bc, 42bc, 68c

THE B. G. CORP.
11b, 13b, 14a

BENSON-LEHNER
13abc, 15abc, 33bc, 42cd, 68cd

BOEING AIRPLANE
4bed, 8abcd, 11abcd-29abcd, 32bed, 33abcd,
34bed, 36bed, 37bed, 39bed, 41abcd, 42bed,
43bed, 45ab, 47abcd, 48abcd, 49bed, 60abcd,
68bed, 69bed, 76bed, 80abcd

BOURNS LABORATORIES
34a

BRISTOL
8c, 13c, 41ab, 42ab

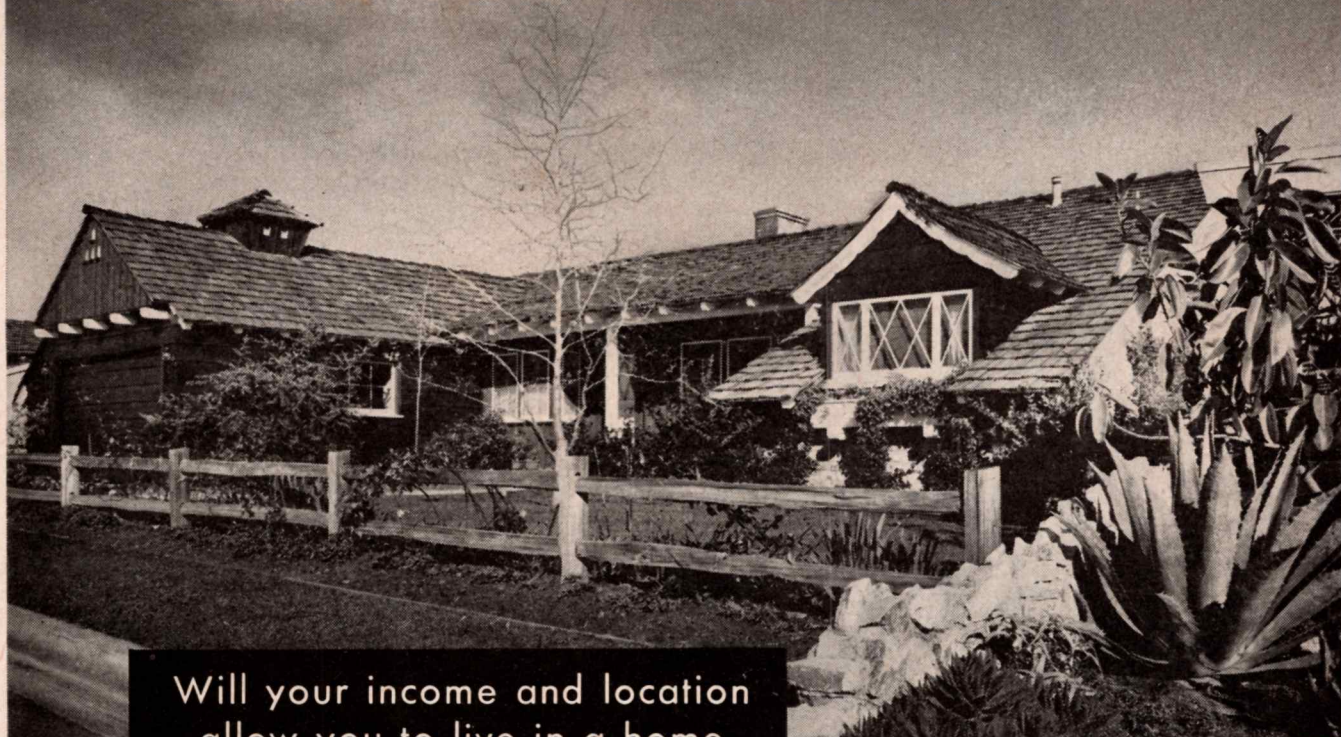
BURTON RODGERS—TECH. TRG.
11ab, 34bc, 68b, 80ab

CALIDYNE
13ab, 27ab, 28a, 34b

CAMBRIDGE CORP.
68b

← For further information circle
Reader Reply No. 31

ENGINEERS... LOOK TEN YEARS AHEAD!



Will your income and location
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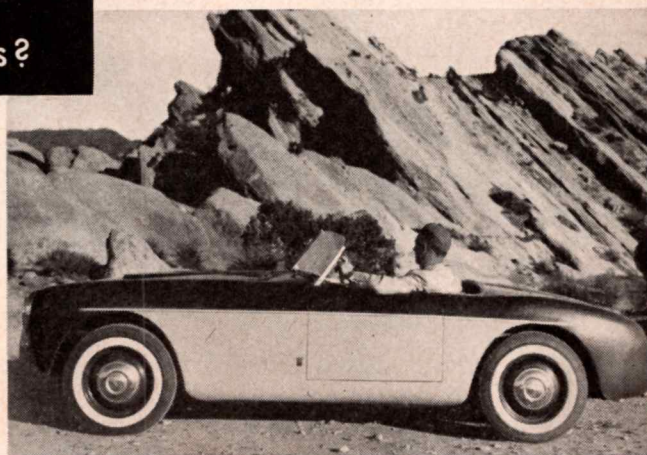
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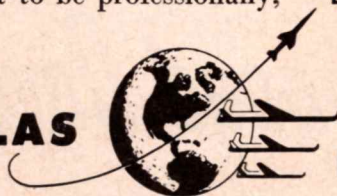
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Chemical

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For further information circle Reader Reply No. 5

Employment

CANADAIR
6abc, 11b, 20b, 22b, 26b, 29b

CBS-HYTRON
13b, 14ab, 24ab

CGS LABORATORIES
13ab, 14cd, 15ab, 17a, 18a, 21ab, 23a, 44a, 68abc

CHANCE VUGHT ACFT.
5ab, 6ab, 9b, 11abc, 13b, 19a, 23ab, 25b, 26abc, 27abc, 28bc, 29abc, 32bc, 34ab, 35b, 37b, 38bc, 40b, 41abc, 42abc, 68cd, 69c, 80c

CLARY CORP.
37abcd, 41abcd

COLLINS RADIO
12b, 13b, 17bc, 21ab, 28bc, 38bc, 80abc

CONTINENTAL AV. & ENG.
7bc, 14ab, 23ab, 27bc, 28b, 34bc, 41abc, 74abc, 75abc, 76b

CONVAIR-FT. WORTH
6abcd, 8abcd, 11abcd-21abcd, 23abcd-29abcd, 32abcd-39abcd, 41abcd-43abcd, 63abcd

CORNELL AERO. LAB.
12b, 13bc, 16bd, 18bd, 19bd, 25bd, 68cd

CORNING GLASS
8ab, 14abc, 30abcd, 44abcd, 68abcd

COX & CO.
11a, 13a, 17b, 24b

CUBIC CORP.
13ab, 15ab, 21ab, 24ab

CURTISS WRIGHT-ELEC. DIV.
13b, 23a, 28bc, 41a, 68ab

DAVIES LABS.
13a, 18a, 34a

DIEHL MFG.
13a-15a, 28a

DIT-MCO
11b, 44b, 67c, 68c

EAGLE SIGNAL
13b-15b, 17b, 27b, 28b, 34b, 42b

THOMAS A. EDISON
13abc, 14abc, 23abc, 24abc, 34abc, 43abc-45abc, 47abc, 68abc

ELECTROL
14abc, 15abc

ERCO DIV., ACF IND.
5a, 13ab, 15ab, 19b, 22b, 28a, 41a, 43a, 80a

FAIRCHILD AIRCRAFT DIV.
11a, 12c, 13b, 14c, 19c, 20c, 26c, 27c, 29bc, 80b

FAIRCHILD ENG. DIV.
34c

FAIRCHILD GUIDED MISSILES DIV.
11abcd-24abcd, 45abcd-48abcd, 68cd, 69cd, 77abcd-80abcd

FAIRCHILD ELECTROTECHNICS
33b, 34c, 41b, 42b, 44b

FLIGHT RESEARCH
24b, 59ab

GE-ACFT, GAS TURBINE DIV. (CINCINNATI)
6ab, 11abc, 13ab, 15abc, 17ab, 3ab, 26ab, 27abc, 28abc, 30ab, 35b, 60b, 63ab

GENERAL ELECTRIC (SCHENECTADY)
2bcd, 5bcd-8bcd, 10bcd-29bcd, 32bcd-13bcd, 46bcd-52bcd, 54bcd-56bcd, 60bcd-66bcd, 68bcd-76bcd, 80bcd, 81bcd

GENERAL MILLS (MECH. DIV.)
6abcd, 12abcd, 15abcd, 18abcd, 19abcd, 27abcd, 33abcd, 34abcd, 38abcd

GENERAL PRECISION LAB.
8bc, 12abcd-14abcd, 15abc, 17abc-23abc, 25abc-28abc, 32abc, 33abcd, 34abc, 37abc-45abc, 52abc, 68abc, 80abc

G. M. GIANNINI
6a, 13b, 14b, 26b, 27c, 28b, 34bc, 41b, 42c, 80a

GRAND CENTRAL ROCKET
2abcd, 7abcd, 8abcd, 10abcd, 11abcd, 23abcd, 69abcd, 70abcd, 76abcd, 80abcd, 81abcd

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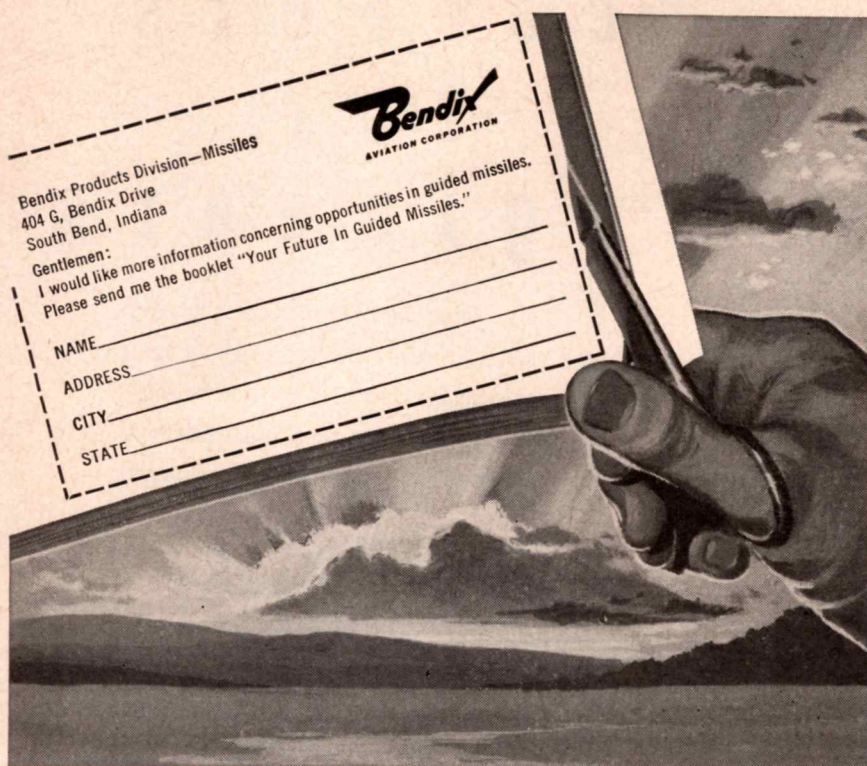
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5-A-61

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Employment

HARNISCHFEGER
8a, 44a

A. W. HAYDON
14abcd, 28abc, 34abc, 41abc, 44ab

HELIPOT
14b, 15b

HETHERINGTON
11a

HOFFMAN ELECTRONICS
2abc, 5abc, 6abc, 12abc-14abc, 16abcd, 21abc-24abc, 26abc-29abc, 32abcd, 34abcd, 38abcd, 39abcd, 41abcd-43abcd, 80a

HOLLEY CARBURETOR
41ab

HOOVER ELECTRONICS
11b, 13ab, 29ad, 80b

HYCON MFG. CO.
13b, 16b, 17a, 18b, 19b, 23a

HYDRO-AIRE
11abcd

JACK & HEINTZ
8ab, 11ab, 17b, 24b, 44a, 80b

K. C. KAHN & CO.
15e

LEAR (SANTA MONICA)
6abcd, 8abcd, 11abcd-15abcd, 17abcd, 21abcd, 23abcd-29abcd, 32abcd-40abcd, 44abcd, 47abcd, 68abcd, 69abcd, 80abcd

LIBRASCOPE, INC.
5abc, 6abc, 13abc-15abc, 17abc, 19abc, 22abc, 24abc, 25abc, 28abc, 45b, 47b, 68c, 80ab

LOCKHEED AIRCRAFT
5abcd, 11abcd-29abcd, 32abcd-43abcd, 60abcd, 80abcd

LOCKHEED GEORGIA DIV.
5e, 11c, 12c, 32c, 42c, 80bc

LOCKHEED (MISSILE SYS. DIV.)
11abcd-21abcd, 23abcd, 24abcd-29abcd, 32abcd-43abcd, 60abcd-66abcd, 80abcd, 81abcd

LUNDY MFG.
8b, 43b

MCDONNELL AIRCRAFT
4a, 5b, 6c, 8a, 9c, 11b, 12b, 13a, 14a, 19b, 24b, 26b, 28b, 29b, 39a, 80b

MAGNAVOX
13ab, 19abc, 21abc, 22b, 28b, 80ab

MANNING, MAXWELL & MOORE
14abc, 15abc, 17abc, 27abc, 28abc, 33abc, 34abc, 41abc, 60abc, 63abc

MARTIN AIRCRAFT—BALTIMORE
11abcd-29abcd

MICRODOT
44ab

MICRONICS
12c, 20b

MORSE INSTRUMENT
13abc

NORTH AMERICAN
11abcd-15abcd, 17abcd-21abcd, 23abcd, 25abcd-29abcd, 32abcd-43abcd

NORTH AMERICAN—COLUMBUS DIV.
6bc, 11abcd, 12abcd-24abcd, 26bc, 28bcd, 29c, 32bc, 38bc

NORTHROP AIRCRAFT (HAWTHORNE, CALIF.)
5abcd, 7abcd, 11abcd-29abcd, 32abcd-43abcd, 80abcd

OMAR (OLIN MATHIESON, MARQUARDT AIRCRAFT, REACTION MOTORS)
11bc, 28bc, 43bc

PACIFIC SCIENTIFIC
34abc, 37abc, 44abc, 54abc

PHILCO—GOV'T & INDUSTRIAL DIV.
6ab, 12ab, 13abc, 14ab, 15abc, 16ab, 19ab, 24ab-26ab, 34ab, 42ab



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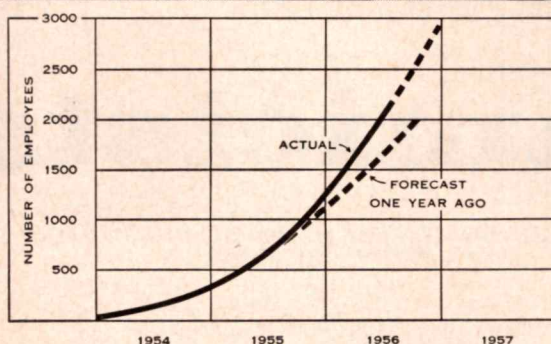
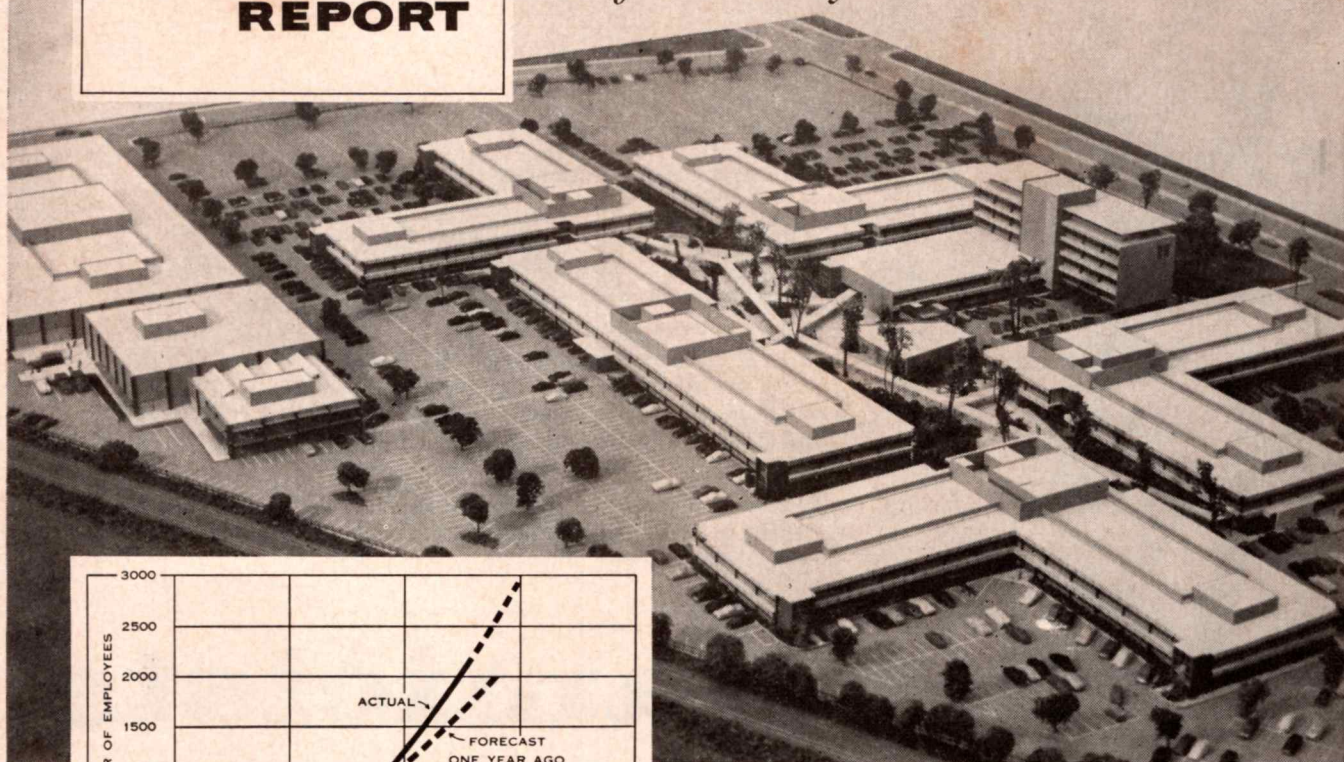
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Supervisor, Engineering Personnel

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PROGRESS REPORT

After Thirty-Four Months...



RESEARCH AND DEVELOPMENT PERSONNEL The above curve shows the growth in Ramo-Wooldridge personnel which has taken place since our Progress Report one year ago. A significant aspect of this growth is the increase in our professional staff which today is made up of 135 Ph.D's, 200 M.S's and 265 B.S's or B.A's. Members of the staff average approximately ten years' experience.

FACILITIES Within the past few months, construction has been completed at our Arbor Vitae complex, which now consists of eight modern buildings of 350,000 square feet, four of which are illustrated at the bottom of the page. Nearby is the R-W flight test facility, including hangar, shop, and laboratories, located on a 7-acre plot at International Airport.

To provide additional space for our continuing growth, construction has been started on an entirely new 40-acre Research and Development Center, located three miles from the Arbor Vitae buildings. The photograph above is of a model of the Center, which we believe will be one of the finest research and development facilities in the country. The first three buildings, now under construction, will total 250,000 square feet.

A second major construction program is underway on a manufacturing plant for quantity production of electronic

systems. The initial unit of the plant, located on a 640-acre site in suburban Denver, Colorado, will be completed next spring and will contain approximately 150,000 square feet.

PROJECTS Our current military contracts support a broad range of advanced work in the fields of modern communications, digital computing and data-processing, fire control systems, instrumentation and test equipment. In the guided missile field, Ramo-Wooldridge has technical direction and systems engineering responsibility for the Air Force Intercontinental and Intermediate Range Ballistic Missiles. Our commercial contracts are in the fields of operations research, automation, and data processing. All this development work is strengthened by a supporting program of basic electronic and aeronautical research.

THE FUTURE As we look back on our first three years of corporate history, we find much to be grateful for. A wide variety of technically challenging contracts have come to us from the military services and from business and industry. We have been fortunate in the men and women who have chosen to join us in the adventure of building a company. We are especially happy about the six hundred scientists and engineers who have associated themselves with R-W. Their talents constitute the really essential ingredient of our operations. We plan to keep firmly in mind the fact that the continued success of The Ramo-Wooldridge Corporation depends on our maintaining an organizational pattern, a professional environment, and methods of operating the company that are unusually well suited to the special needs of the professional scientist and engineer.

The Ramo-Wooldridge Corporation

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2abed, 4abed-6abed, 9abed, 11abed-25abed, 27abed-29abed, 32abed-44abed, 67ed-69ed, 80abed

JOSEPH POLLAK CORP.

14b

RCA—CAMDEN, N. J.

5abc, 6abc, 12abc-26abc, 28abc, 29ab, 33abc-35abc, 38abc, 40abc-43abc, 68ed, 69ed, 80abc

REACTION MOTORS

28b, 43bc

REPUBLIC AVIATION (GUIDED MISSILES DIV.)

11abed, 13abed, 15abed, 16abed, 19abed, 25abed-28abed, 32abed, 33abed, 37abed-42abed, 80abed

REVERE

14abc, 34c, 36abc, 68c, 81bc

ROCKETDYNE—DIV. OF NORTH AMERICAN

8abc, 11abc, 13abc, 15abc, 17abc, 18abc, 23abc, 33abc-36abc, 39abc-43abc, 60abc, 63abc, 71abc, 75abc, 76abc

RYAN AERONAUTICAL

11bc, 13b, 17c, 18b, 19b, 25b-29b

SERVOMECHANISMS (HAWTHORNE, CALIF.)

5abed, 13abed, 17abed, 25abed, 28abed, 33abed, 41abed, 42abed, 68abed

SHAW & ESTES

42b

STUDEBAKER-PACKARD

11a, 80a

SUNDSTRAND MACH. TOOL (AVIATION DIV.)

11ac, 13ac, 15ac, 17ac, 33ac, 41ac, 52ac, 80ac

TEMCO AIRCRAFT

5abed, 6abed, 11abed, 12abed-29abed, 32bed-43bed

TITEFLEX INC.

11b

TRANE CO.

44ab

UNION SWITCH & SIGNAL—DIV. WESTINGHOUSE

AIR BRAKE

8ab, 13ab, 15ab, 24ab, 36ab, 41ab, 42ab, 80ab

UNITED STATES TESTING CO.

14ab, 23ab

VARO MFG.

11b, 13ab, 23ab, 27b

WAC LINE

11b, 15b, 17bc, 24bc, 25b, 33bc, 41bc, 44bc

WINZEN RESEARCH

13b

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AEROJET—GENERAL

15ab, 16ab, 25ab, 26ab, 37ab, 59ab, 61ab, 62ab, 66ab, 73ab, 81ab

AC SPARK PLUG

57bc

AIRCRAFT CONTROLS

63b

AIRCRAFT MARINE PRODUCTS

59abc

AIRESEARCH MFG. CO. OF ARIZ.

23ab, 57abc

ALLISON DIV.—GMC

10abc, 40bed, 57bed, 66ed

ANDERSON, GREENWOOD & CO.

70a, 73a

ATOMIC INTERNATIONAL—DIV. OF NORTH AMERICAN

44bed, 59abed, 60abed-66abed, 79bc, 80abc

AUTONETICS DIV. & MISSILE DEVEL. ENG.—NORTH AMERICAN

2abed, 5abed, 6abed, 9abed, 10abed, 12abed-29abed, 32abed-43abed, 69ed, 77abed-79abed

AVCO MFG.—ADVANCED DEVELOPMENT DIV.

31c, 59d, 62b, 63b, 73b

AVRO AIRCRAFT

10b

BELL AIRCRAFT (BUFFALO)

10b, 12abc, 17c, 21abc, 32abc, 34bc, 37bc

BELL AIRCRAFT—FT. WORTH

81a

BENDIX AVIATION (FRIEZ INST. DIV.)

59bed

BENDIX AVIATION—SCINTILLA DIV.

59ab

BENDIX COMPUTER

15abed

BOEING AIRPLANE

8abed, 57abed-60abed, 62abed-66abed

CAMBRIDGE CORP.

8b, 62b, 63b

CANADAIR

15b, 25b

CBS—HYTRON

24ab

CHANCE VOUGHT ACFT.

6c, 9c, 10c, 11bc, 25bc-29bc, 34bc, 37bc, 38bc, 40abc, 41bc, 77bc, 78bc, 80c, 81ab

CHANDLER-EVANS

30a, 41a

CHRYSLER CORP.—ENGINEERING DIV.

57a

CONTINENTAL AV. & ENG.

23ab, 56abc, 70bc, 71b, 74abc, 75abc, 78b, 79b

CONVAIR—FT. WORTH

6abed, 15abed, 25abed, 26abed, 33abed, 40abed, 57abed, 59abed-62abed, 66abed, 81abed

CORNELL AERO. LAB.

25bd, 27bd, 34ac, 35ac, 38ac, 52bd

CORNING GLASS

8ab, 44abed

CURTISS WRIGHT—ELEC. DIV.

15b

FAIRCHILD AIRCRAFT DIV.

43b, 77c

FAIRCHILD ELECTROTECHNICS

62b

FAIRCHILD ENG. DIV.

59d, 78bed, 79bed

FAIRCHILD GUIDED MISSILES DIV.

77abed-80abed

FLIGHT RESEARCH

24b, 59ab

GE-ACFT, GAS TURBINE DIV. (CINCINNATI)

9ab, 11ab, 13abc, 15abc, 17ab, 26b, 27ab, 28abc, 30ab, 59b

GENERAL ELECTRIC (SCHENECTADY)

8bed, 10bed-29bed, 32bed-43bed, 46bed-48bed, 60bed-66bed, 68bed-76bed, 80bed, 81bed

GENERAL MILLS (MECH. DIV.)

16abed, 27abed, 29abed, 57abed, 59abed, 70abed, 77abed

GENERAL PRECISION LAB.

57abed, 58abed

G. M. GIANNINI

42c

GRAND CENTRAL ROCKET

8abed, 59abed, 62abed, 63abed, 69abed, 70abed, 76abed, 78abed, 80abed, 81abed

HOFFMAN ELECTRONICS

14abed-19abed, 21abed-24abed, 26abed, 27abed

HOLLEY CARBURETOR

60ab

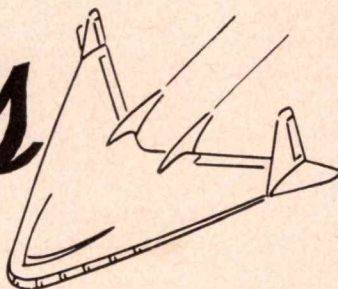
KETT CORP.

62b, 64b

LEAR (SANTA MONICA)

25abed

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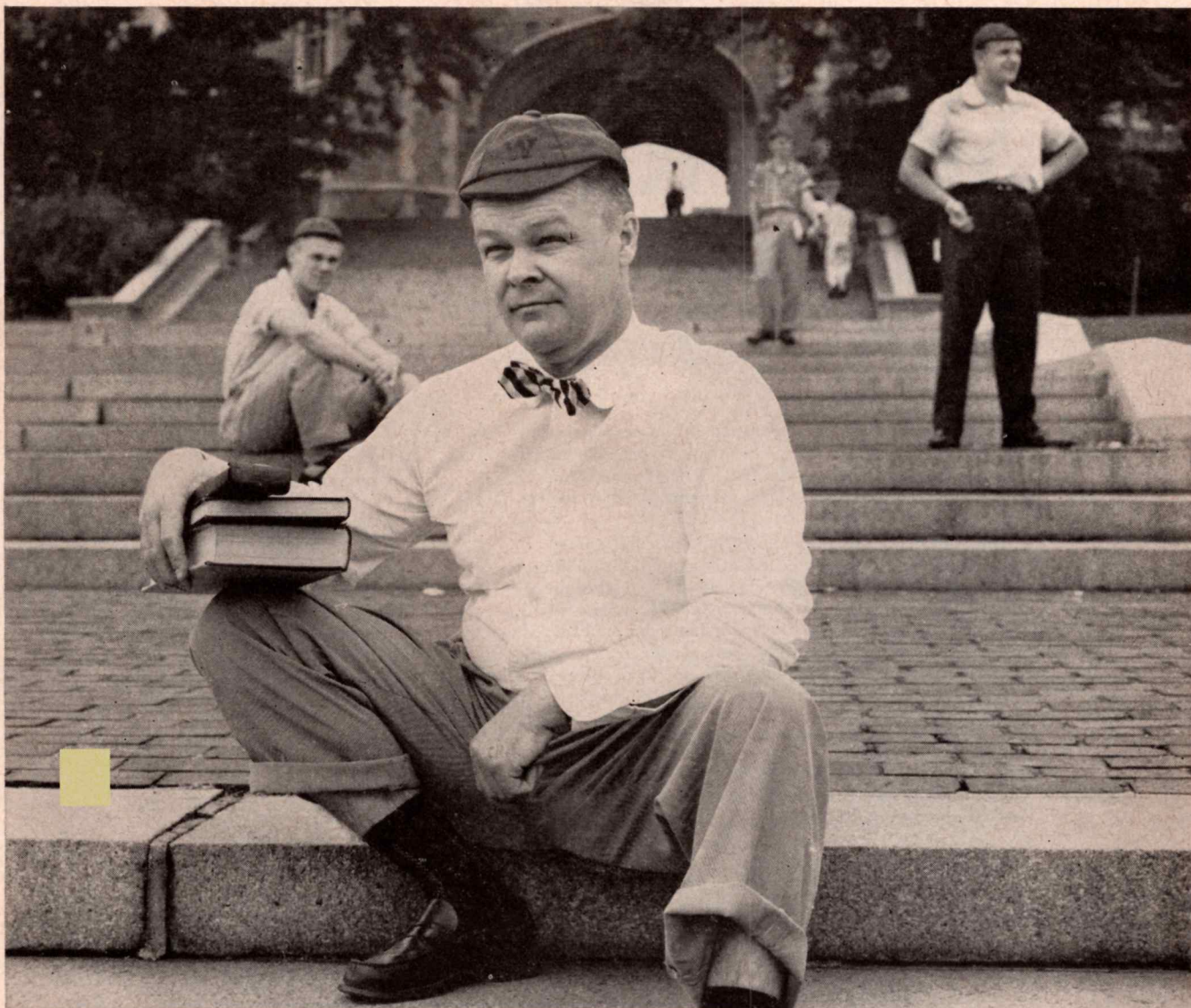


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GENERAL  ELECTRIC

Cincinnati 15, Ohio

For further information circle Reader Reply No. 21

Employment

LIBRASCOPE INC.
5abc, 6ab, 15abc, 25abc

LOCKHEED AIRCRAFT
12abcd-24abcd, 57abcd, 60abcd

LOCKHEED GEORGIA DIV.
10bc

LOCKHEED (MISSILE SYS. DIV.)
2abcd, 4abcd-8abcd, 11abcd-21abcd, 23abcd-29abcd, 32abcd-43abcd, 60abcd-66abcd, 80abcd, 81abcd

McDONNELL AIRCRAFT
9c, 26b, 57cd

MAGNAVOX
57abc

MANNING, MAXWELL & MOORE
27abc, 34abc, 41abc, 55abc, 63abc

MARTIN AIRCRAFT—BALTIMORE
5abcd-7abcd, 9abcd-30abcd, 32abcd-34abcd, 35abc, 38abcd, 40abcd-42abcd, 57abcd-63abcd, 66abcd, 67abcd, 69abcd, 70abcd, 73abcd, 77abcd-80abcd

MICRONICS
12c, 16b, 20b

NORTH AMERICAN
1abcd, 2abcd, 13abcd, 42abcd, 70abcd

NORTH AMERICAN—COLUMBUS DIV.
9bcd, 10bcd, 59bc

NORTHROP AIRCRAFT (HAWTHORNE, CALIF.)
1abcd-3abcd, 5abcd, 7abcd-43abcd, 57abcd-59abcd, 70abcd-81abcd

OMAR (OLIN MATHIESON, MARQUARDT AIRCRAFT, REACTION MOTORS)
8bc, 10bc

PHILCO—GOV'T & INDUSTRIAL DIV.
15abc, 57ab

RCA—CANDEN, N. J.
5abc, 6abc, 11abc-26abc, 29abc, 40abc, 57abc, 59abc

REPUBLIC AVIATION (GUIDED MISSILES DIV.)
25bcd-29bcd

ROCKETDYNE—DIV. OF NORTH AMERICAN
2abc, 10abcd, 31abcd, 33abc, 34abc, 36abc, 40abc-42abc, 49abc, 56abc, 60abc-63abc, 66abc, 70abc, 72abc, 73abcd, 75abcd, 76abcd

SERVOMECHANISMS (HAWTHORNE, CALIF.)
15abcd, 16abcd, 24abcd, 25abcd, 38abcd, 41abcd, 42abcd

SHAW & ESTES
57b

UNION SWITCH & SIGNAL—DIV. WESTINGHOUSE BRAKE
33ab, 59ab, 70ab, 80ab, 81ab

VARO MFG.
57c, 58c

WINZEN RESEARCH
59a

Mechanical Engineering Degree Preferred

ABRAMS INSTR.
5bc, 34bc, 41b

AC SPARK PLUG DIV.
8b, 39b, 41ab, 80b

ADEL PRECISION PROD.
8bc, 28bc

AEROJET—GENERAL
5ab-8ab, 28ab, 30ab, 31ab, 34ab, 37ab, 41ab, 49ab, 51ab-56ab, 60ab, 69ab, 71ab, 73ab, 76ab, 78ab, 81ab

AERO SUPPLY
8c,

AIRCRAFT CONTROLS
8ab, 30abc, 36abc, 41abc, 51abc, 55abc

AIRCRAFT ENG. PROD.
8b, 47c, 48c

AIRCRAFT-MARINE PROD.
8abc, 52abc, 54abc

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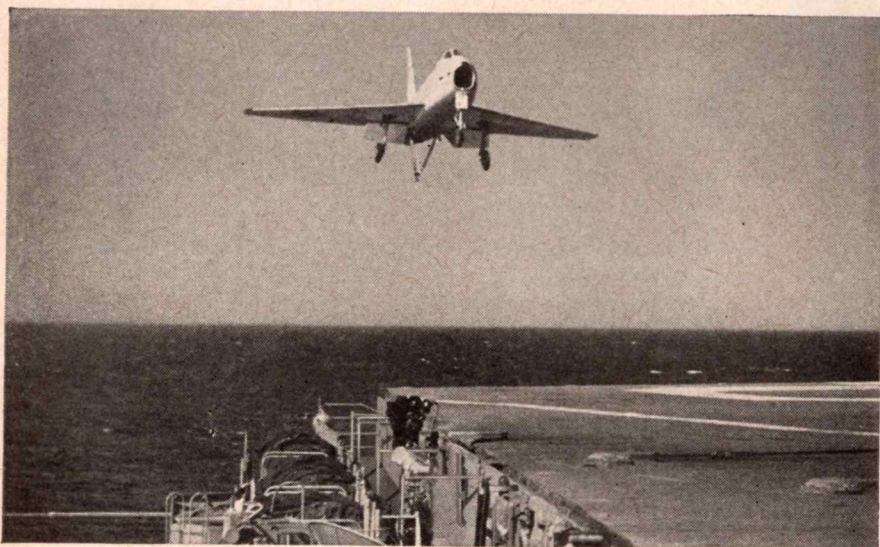
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COLUMBUS DIVISION

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Employment

AIRESEARCH MFG. CO. OF ARIZ.
3abed, 8a, 10abc, 42abed, 43ab, 52abc, 55abed,
56abed, 70abed, 71abed, 80a

ALL AMERICAN ENGINEERING
53c

ALLISON DIV.—GMC
10abc, 30bed, 34bed, 35be, 36ab, 40bed-42bed,
43abed, 48ab, 54bed, 56bed, 60cd, 62cd, 63cd,
73bed, 75bed, 77bed, 78abed, 79abed, 75abed,
76abed, 80abed

AMPICO METAL
46a, 64a

ANDERSON, GREENWOOD & CO.
30abc, 47ab, 52abc, 53ab, 54ab, 55abed, 70ab,
73ab, 76ab, 80a

ATOMIC INTERNATIONAL—DIV. OF
NORTH AMERICAN
44bed, 49abc, 52abc, 60abed-66abed, 79bc, 80abc

AUTONETICS DIV. & MISSILE DEVEL. ENG.—
NORTH AMERICAN
2abed, 4abed-8abed, 10abed, 26abc, 30abed,
37abed, 41abc, 49abed-56abed, 69cd, 70abed-
79abed, 81a

AVCO MFG.—ADVANCED DEVELOPMENT DIV.
5b, 28b, 35b, 39b, 40b, 41c-43c, 68c, 69c, 81b

AVRO AIRCRAFT
4b, 30b, 51b, 80bc

BAY STATE ABRASIVE
8a, 30ab, 52b, 54b

BELL AIRCRAFT (BUFFALO)
6bc, 7a, 10b, 30abc

BELL AIRCRAFT—FT. WORTH
30ab, 52a, 81ab

BENDIX AVIATION (FRIEZ INST. DIV.)
52b

BENDIX AVIATION—SCINTILLA DIV.
8ab, 34ab, 52ab, 73ab, 78ab

BENDIX AVIATION—UTICA DIV.
8a, 49b-52b, 54b-56b

BENDIX COMPUTER
15abed

BENDIX PROD. DIV., MISSILES (INDIANA)
8bc, 30bc, 39bed, 69bc, 72bc, 73bc, 76bc, 77bed,
78bc-80bc

BENDIX RADIO DIV., BENDIX AVIATION
12b, 15b, 19b, 38b, 39b

THE B. G. CORP.
42a

BENSON-LEHNER
44ab, 45cd, 54abc

BOEING AIRPLANE
5abed, 8abed-11abed, 30abed-32abed, 36abed,
37abed, 39abed-45abed, 46ab, 47abed-49abed,
51abed, 52abed, 54abed-56abed, 70abed, 73abed,
75abed, 76abed, 80abed

BOURNS LABORATORIES
34a, 36a

BROOKS & PERKINS
52a-54a

BURTON RODGERS—TECH. TRG.
4b, 8abc, 33b, 52abc, 54bc, 80b

CALIDYNE
8a, 10bc, 52c

CAMBRIDGE CORP.
8b, 79b

CANADAIR
5abc, 28b, 70b, 81b

CHANCE VOUGHT ACFT.
4abc, 5abc, 30abc, 32b, 34b, 37bc, 39ab, 49ab,
50b, 51ab-55ab, 73ab, 75ab, 76ab, 80b, 81abc

CHANDLER-EVANS
8ab, 30ab, 41ab, 52ab, 54ab

CHRYSLER CORP.—ENGINEERING DIV.
10a, 30ab, 49ab, 54ab, 56ab, 80ab

CLARY CORP.
28abed, 37abed, 41abed, 54abed, 55abed



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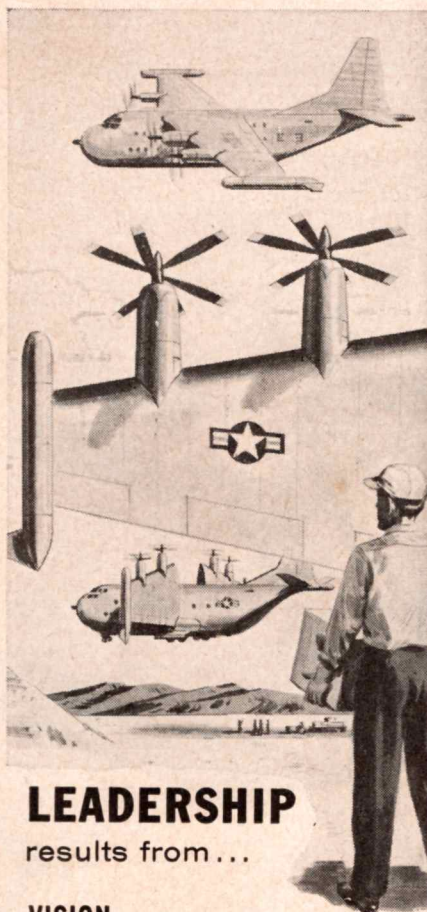
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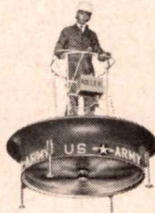
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Employment

CLEVELAND PNEUMATIC TOOL
8a, 30ab, 51bc, 52b, 54bc, 79abc

COLLINS RADIO
54abc

CONTINENTAL AV. & ENG.
2b, 7bc, 10ab, 14ab, 23ab, 27bc, 28b, 30b, 34bc, 41abc, 52abc, 54b, 55b, 56abc, 71b, 73b, 74abc, 75abc, 76b, 78b, 79b, 80a

CONVAIR--FT. WORTH
4abcd, 5abcd, 8abcd, 9abcd, 30abcd, 41abcd, 45abcd, 47abcd-56abcd, 62abcd, 70abcd-73abcd, 75abc, 76abc, 79abcd

CORNELL AERO. LAB.
52b, 79b

CORNING GLASS
8ab, 30abcd, 34abcd, 44abcd

CURTISS WRIGHT--ELEC. DIV.
54b

DAVIES LABS.
52c

DELAVAN MFG.
8abcd, 10abcd, 30abcd, 31abcd, 36abcd, 42abcd, 44abcd, 45abcd, 52abcd

DIT-MCO
52b

DRESSER-IDECO
52bc, 54b

EAGLE SIGNAL
34b, 42b, 47b, 48b, 54b

THOMAS A. EDISON
8abc, 14abc, 34abc, 44abc, 45abc, 47abc, 48abc, 68abc

ELECTROL
30abcd, 55abcd

ERCO DIV., ACF IND.
8a, 28a, 52ab, 54ab

FAIRCHILD AIRCRAFT DIV.
1c, 4c, 30c, 32ac, 35c, 43ac, 53c, 75bc, 76b, 81b

FAIRCHILD ELECTOTECHNICS
8b, 46c

FAIRCHILD ENG. DIV.
1b, 8c, 9b, 34c, 52ab, 56bcd, 70bcd, 75abcd, 78bcd, 79bcd

FAIRCHILD GUIDED MISSILES DIV.
45abcd-48abcd, 77abcd-81abcd

FLIGHT RESEARCH
8abc

FORD MOTOR--AIRCRAFT ENGINE DIV.
8abc, 35abc 43ab, 45abc-48abc

GE-ACFT. GAS TURBINE DIV. (CINCINNATI)
6ab, 8ab, 9abc, 10abc, 15bc, 27abc, 28abc, 30abc, 35ab, 44abcd-46abcd, 49ab, 54ab, 56abc, 62ab, 63ab, 70ab, 73ab, 74abc, 75ab, 76ab, 77abcd-79abcd, 81ab

GENERAL ELECTRIC (SCHENECTADY)
2bcd, 5bcd-8bcd, 10bcd-30bcd, 32bcd-43bcd, 46bcd-56bcd, 60bcd-66bcd, 68bcd-81bcd

GENERAL MILLS (MECH. DIV.)
8abcd-10abcd, 34abcd, 39abcd-42abcd, 54abcd, 55abcd, 71abcd, 73abcd, 77abcd-79abcd, 81abcd

GENERAL PRECISION LAB.
8bc, 39abcd

G. M. GIANNINI
6a, 34bc, 37bc, 41b, 42c, 80a

GRAND CENTRAL ROCKET
2 abcd, 7abcd, 8abcd, 30abcd, 44abcd, 45abcd, 47abcd, 48abcd, 50abcd, 52abcd, 54abcd, 69abcd, 70abcd, 76abcd, 79abcd-81abcd

HARNISCHFEGER
8a, 44a, 52a, 74a

A. W. HAYDON
54abc

HELIPOT
47b, 51b

HETHERINGTON
52a, 54a

HEXEL PRODUCTS
8abcd, 54abcd

HOFFMAN ELECTRONICS
2abc, 5abc, 6abc, 12abc-14abc, 16abc-19abc, 21abc-24abc, 26abc-29abc, 34abc, 38abc, 39abc-43abc, 51abcd, 52abcd, 54abcd

HOLLEY CARBURETOR
8a, 30ab, 54ab, 80abc

HOOVER ELECTRONICS
54c

HYCON MFG. CO.
34b, 52a, 54ac

HYDRAULIC PRESS MFG. CO.
8a, 30bc, 52bc

HYDRO-AIRE, INC.
8a, 30bcd, 54bcd, 55bcd

JACK & HEINTZ
8ab, 11ab, 46b, 48b, 50ab

JANITROL DIV.--SURFACE COMBUSTION CORP.
30b, 49b, 51b, 55b, 56b

K. C. KAHN & CO.
30b

KETT CORP.
52b, 56b

LEAR (SANTA MONICA)
8abcd, 30abcd, 41abcd-43abcd, 50abcd, 52abcd, 54abcd, 55abcd, 56abcd, 79abcd

LIBRASCOPE, INC.
5abc, 6abc, 15abc, 25abc, 28abc, 45b, 47b, 54abc, 80abc

LOCKHEED AIRCRAFT
4abcd, 8abcd, 25abcd-31abcd, 49abcd-56abcd, 62abcd

LOCKHEED GEORGIA DIV.
4bcd, 5c, 8b, 10bc, 30c, 31c, 32c, 35bc, 45bc, 46d, 51cd, 52cd, 54c, 70c, 73c, 78c, 80bc

LOCKHEED (MISSILE SYS. DIV.)
2abcd, 4abcd-11abcd, 25abcd-30abcd, 32abcd-43abcd, 49abcd, 70abcd, 73abcd, 76abcd-81abcd

LUNDY MFG.
8b, 34c, 52b, 54b

McDONNELL AIRCRAFT
4a, 5b, 6c, 8a, 9c, 28b, 35b, 39a, 40b, 45c-48c, 49b, 51b-55b, 69d, 80b

MAGNAFLUX
44a

MAGNAVOX
19ab, 21ab, 54ab, 57abc

MANNING, MAXWELL & MOORE
27abc, 28abc, 30abc, 41abc, 54abc, 55abc, 62abc

MARTIN AIRCRAFT--BALTIMORE
1abcd-10abcd, 28abcd, 30abcd-34abcd, 35abc, 36abcd-39abcd, 41abcd, 42abcd, 44abcd, 46abcd-55abcd, 57abcd, 58abcd, 60abcd-67abcd, 69abcd, 77abcd-81abcd

MELETRON
34a, 54a

MICHIGAN SEAMLESS TUBE
47a

MORSE INSTRUMENT
52abc

NEW YORK AIR BRAKE
8ab, 28b, 30abcd

NIPPET ELECTRIC
8a

NORTH AMERICAN
5abcd-8abcd, 30abcd, 49abcd, 51abcd-56abcd, 70abcd, 72abcd, 73abcd, 75abcd, 76abcd, 78abcd, 79abcd, 81abcd

NORTH AMERICAN--COLUMBUS DIV.
4abcd, 5b, 28bcd, 30bcd, 34bc, 49bc, 51abcd, 54bc, 73bc, 75bcd, 80a

NORTHROP AIRCRAFT (HAWTHORNE, CALIF.)
1abcd-4abcd, 8abcd-10abcd, 30abcd-33abcd, 39abcd, 48abcd-56abcd, 77abcd-81abcd

OMAR (OLIN MATHIESON, MARQUARDT AIRCRAFT, REACTION MOTORS)
6bc-8bc, 10bc, 28bc, 30bc, 41bc, 44bc, 50bc, 52bc, 53bc, 56bc, 60bc, 62bc, 64bc, 73bc, 76bc, 78bc-80bc

Employment

PACIFIC SCIENTIFIC
34abc, 37abc, 44abc, 51abc, 54abc

PSC APPLIED RESEARCH
2abcd, 4abcd-6abcd, 9abcd, 11abcd-25abcd, 27abcd-
29abcd, 32abcd-44abcd, 67cd-69cd, 80abcd

PERFECT CIRCLE CORP.
44a, 46a, 47a, 48a, 74a

PHEOLL MFG. CO.
8b

PHILCO—GOV'T & INDUSTRIAL DIV.
8ab, 28ab, 49ab, 54ab, 55ab

JOSEPH POLLACK CORP.
14b

PREWITT AIRCRAFT
4b, 8a, 45c, 48b, 52b

RCA—CAMDEN, N. J.
5abc, 6abc, 11abc-26abc, 28abc, 33abc, 34abc,
41abc-43abc, 45abc, 47abc, 54abc, 68cd, 69cd, 80abc

REACTION MOTORS
7a, 30b, 62c, 76c, 80b

REPUBLIC AVIATION (GUIDED MISSILE DIV.)
6abcd, 52abcd, 54abcd, 69cd, 80abcd, 81abcd

RESISTOFLEX
30bc, 51c, 55c, 67d

REVERE
36abc, 54abc

ROCKETDYNE—DIV. OF NORTH AMERICAN
2abc, 8abc, 9abc, 10abcd, 30abc, 31abc, 34abc-
36abc, 39abc-43abc, 45abc-52abc, 54abc, 55abc,
56abcd, 60abc-62abc, 66abc, 71abc, 72abc, 73abcd,
74abc, 75abcd, 76abcd, 78abc, 79abc, 81abc

RONAN & KUNZL
72a, 76a

ROYLYN, INC.
30c, 54b, 55b, 80b

SARGENT ENGINEERING
30b, 54a

SERVOMECHANISMS (HAWTHORNE, CALIF.)
8abcd, 33abcd, 39abcd, 52abcd, 54abcd, 68abcd

SHAW & ESTES
8ab, 75b, 76b

STOKES MOLDED PROD.
45b

STUDEBAKER-PACKARD
8a, 44a, 80a

SUNDSTRAND MACH. TOOL (AVIATION DIV.)
30ac, 41ac, 45ac, 46ac, 52ac, 54ac, 80ac

TEMCO AIRCRAFT
4abcd, 27abcd, 28abcd, 30abcd, 32bcd-43bcd,
49abcd-55abcd, 70abcd-76abcd

TITEFLEX INC.
8b, 30b, 44c, 47bc, 48b, 49b, 52b, 55b, 64bc

TRANE CO.
8ab, 44ab, 48a, 49abc, 62abc

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WESTINGHOUSE AIR BRAKE**
39ab, 52ab, 54ab, 55ab

UNITED MFG. CO.
30bc, 55b

UNITED STATES TESTING CO.
49a

VARO MFG. CO.
8a, 52b

WINZEN RESEARCH
2c, 52c

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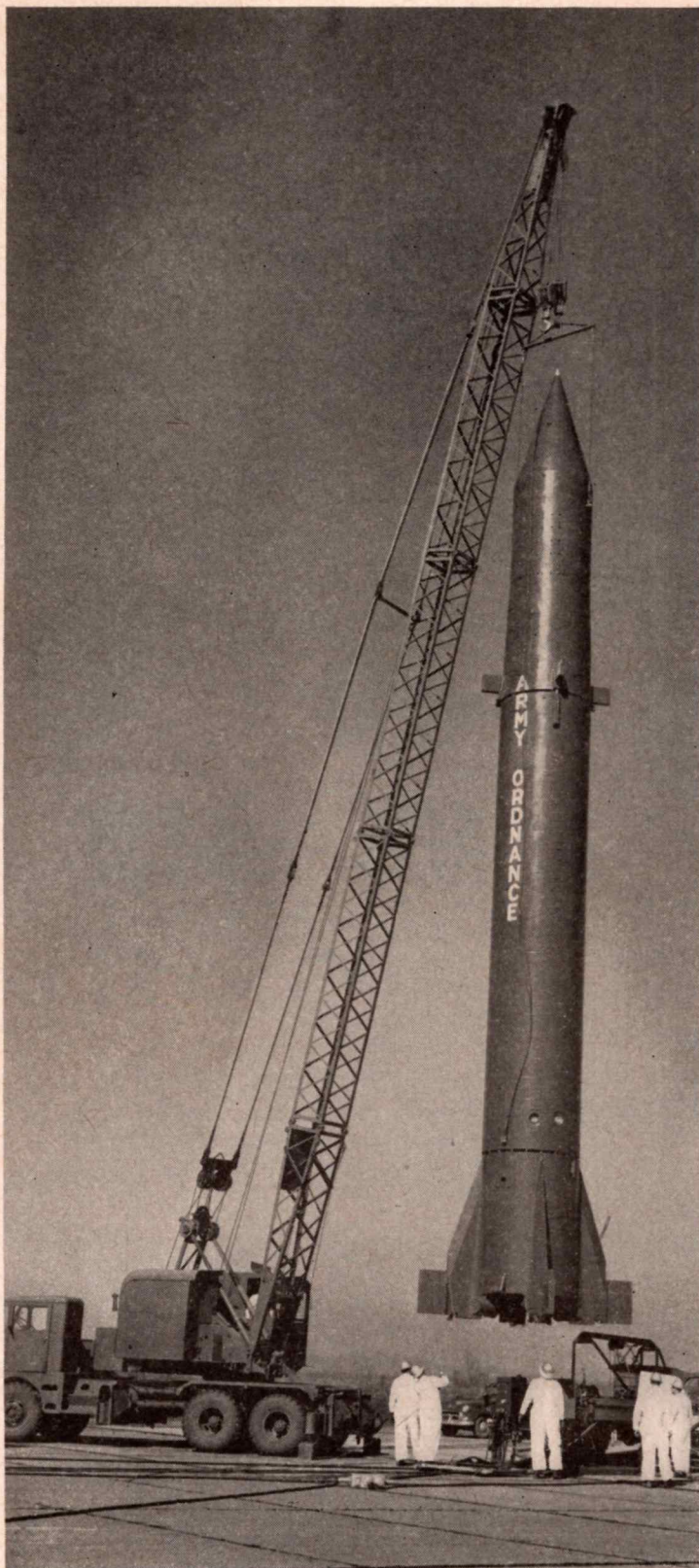
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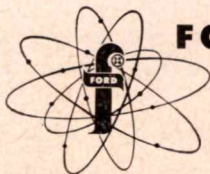
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DIVISION OF SPERRY RAND CORPORATION

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AERO DIGEST

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M. B. Lynch, Chief Eng.
- AIRCRAFT-MARINE PRODUCTS, INC.**
2100 Paxton St., Harrisburg, Pa.
Eduard E. Warren, Employment Mgr.
- AIRESEARCH MFG. CO. OF ARIZONA**
402 S. 36th St., Phoenix, Ariz.
L. H. Derksen
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Box USS 2668, DuPont Airport
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Walton L. Jones, Asst. Pers. Mgr.
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Box 894, Indianapolis 6, Ind.
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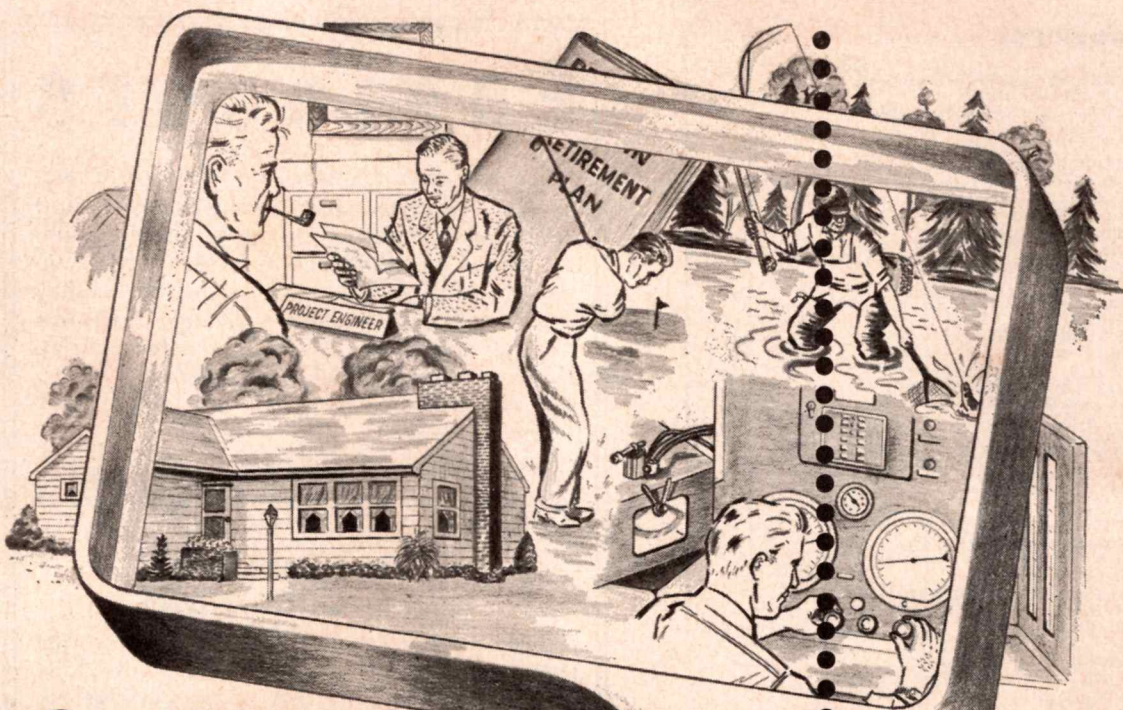
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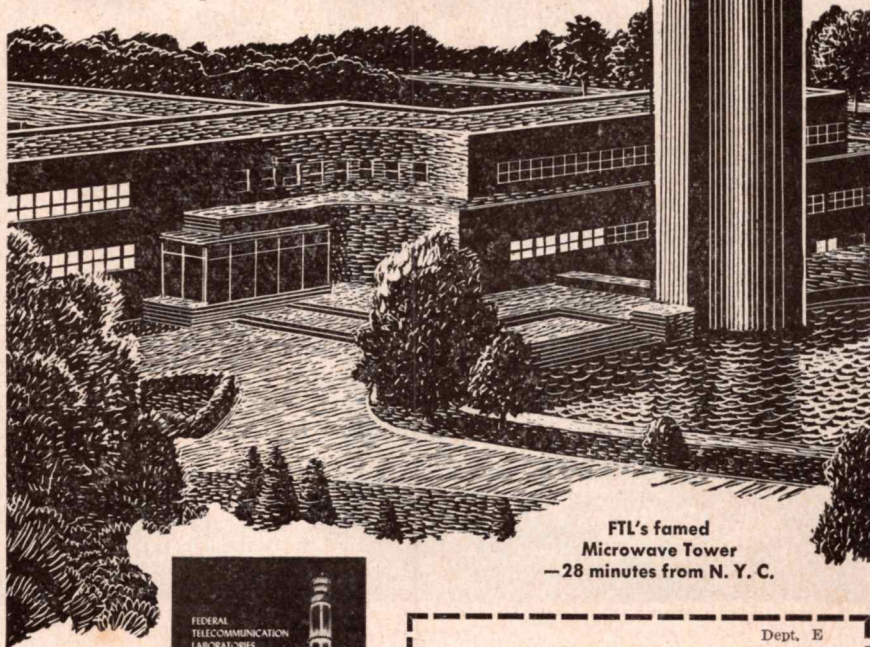
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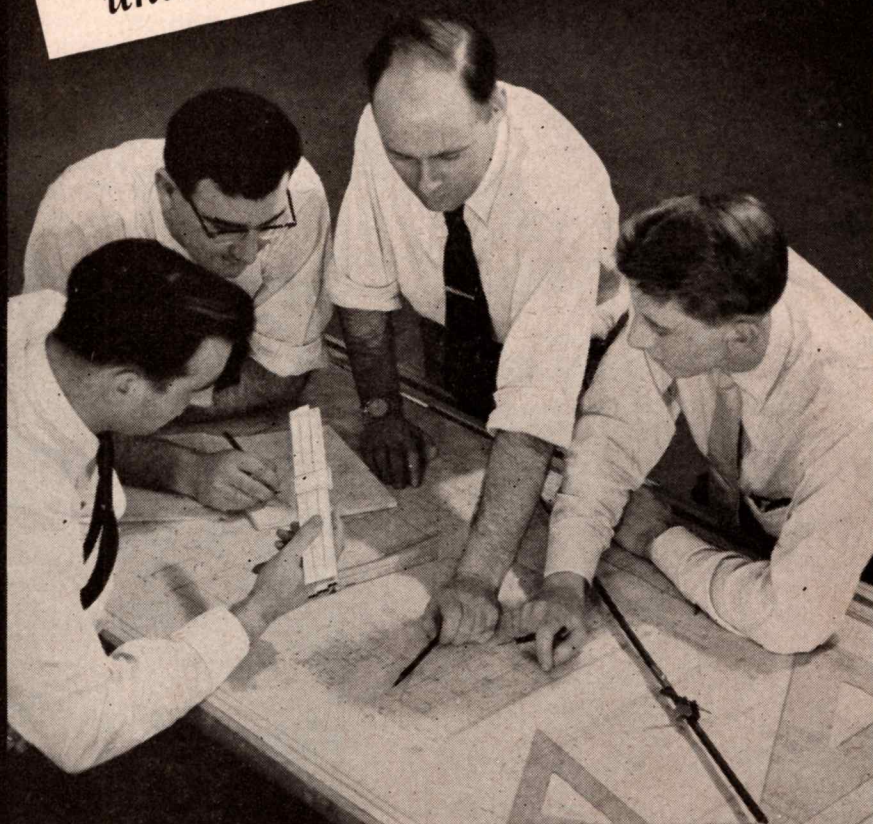
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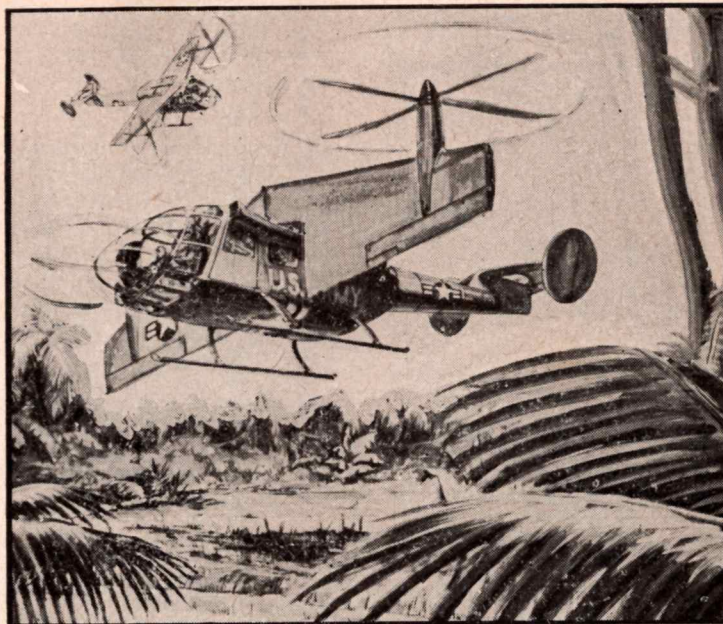
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The subcommittee viewed the problem in two parts: What can industry and the government do to stimulate a greater desire among our youth for the scientific and engineering vacancies that exist? What charges may be allowed against airframe contracts in cost allowances for the contributions, in money, made by industry to stimulate the recruitment of scientific and engineering personnel and to develop personnel resources in the schools?

● ● Scientific Studies Neglected

The shortage of engineers and scientists may in large part be laid to our school systems where the fault "is not wholly their lack of money." Data from an Atomic Energy Commission study show that half of our high schools do not teach mathematics beyond introductory algebra; and half of our high schools offer little or no instruction in physics or chemistry.

According to the subcommittee, the airframe companies have "in a commendable fashion . . . endeavored to do something to stimulate interest and to encourage high school students in the sciences and in mathematics."

The subcommittee said that in the last 50 years, the percentage of high school pupils studying algebra has dropped from 52 to 27 percent; those studying geometry, from 27 to 13 percent; while students of physics have dropped from 23 to 4 percent; and chemistry, from 10 to 7 percent. The grave point is that the trend seems downward.

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In summary, the subcommittee stated that the only satisfactory solution is to produce more engineers and scientists from our school systems. "Therefore, aid in that field is, we believe, a legitimate charge against the present (aircraft) contracts."

END

ENGINEER

There are a few openings in General Electric's Small Aircraft Engine Department for well qualified engineers who have the ability to participate in and lead the development of the following fields:

- Applied Mechanics • Aerodynamics
- Thermodynamics • Mechanical Design
- Mechanical Laboratory Experimentation

Men with mature engineering judgment and at least 3 to 5 years' experience in late model aircraft power plant analysis and design plus, in some cases, a proven ability in supervision.

These are not typical engineering positions. The work is of extremely advanced nature and the promotional opportunity is clearly outlined. The salary is commensurate with ability and is coupled with many additional benefits.

The plant location near Boston is fine for family living. The operation offers stability in its product appeal to both commercial and military markets.

For further information write, giving details of education and experience to:

MR. T. S. WOERZ (Section 2-B)

SMALL AIRCRAFT ENGINE DEPT.

GENERAL  ELECTRIC

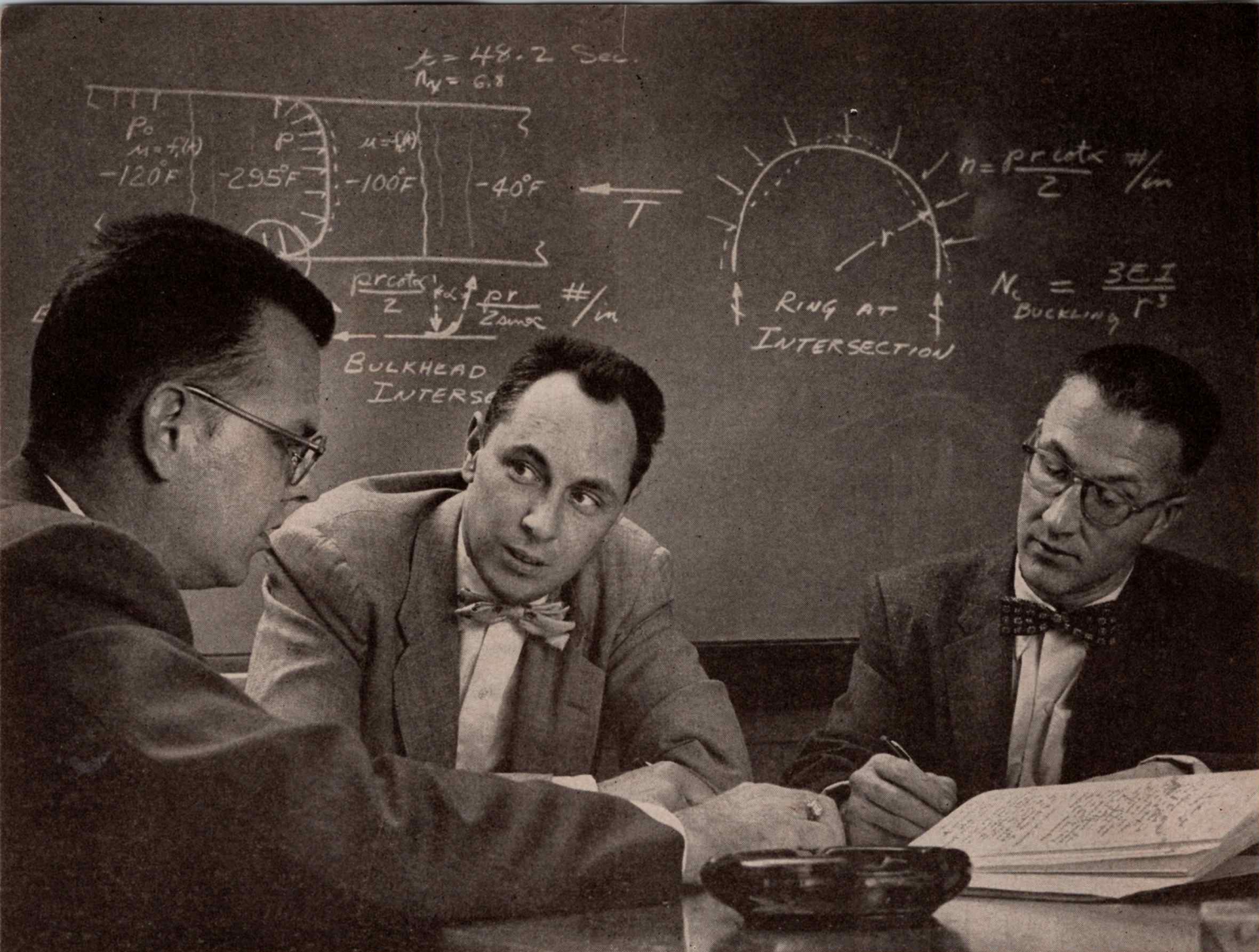
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L. A. Riedinger (center) Design Specialist, J. E. Jean (left) Stress Group Engineer, and J. A. Johnson, head of the Structures Engineering Department, discuss structural effects of high thermal gradients in thin wall pressure vessels.

TRANSIENT THERMAL STRESS IN MISSILE SYSTEMS

The ever increasing performance requirements of guided missiles are paralleled by structures problems that grow constantly in complexity. Of these, transient thermal stress is one of the most urgent in light of projected new developments.

Several approaches offer solutions to this problem. Both new design concepts and advanced methods of analysis, utilizing the most modern computers, present favorable avenues of solving structures problems such as transient thermal stress.

Other areas of interest include:

- Thermal buckling and stress investigation.
- Structural optimization in time-temperature environment.
- Structural dynamics including acoustic vibration, flutter, vibration isolation and dynamics of elastic bodies.
- Evaluation of materials for high temperature strength and short time creep properties.

Those possessing a high order of ability and interest in these fields are invited to write. Please address inquiries to the Research and Engineering Staff at Van Nuys.

Lockheed **MISSILE SYSTEMS DIVISION**
research and engineering staff

LOCKHEED AIRCRAFT CORPORATION
VAN NUYS • PALO ALTO • SUNNYVALE • CALIFORNIA

BRITISH BUILD POROUS TRANSONIC WIND TUNNEL

Shock-wave reflections cut down by using perforated steel plates in tunnel's working section.

R. A. COLE
AERO DIGEST European Editor

TO HELP OVERCOME the shortage of wind-tunnel accommodations available to British designers, the majority of prominent manufacturers have pooled their financial resources to build a large transonic tunnel.

The tunnel, Figure 1, has a working section 9 feet by 8 feet. To avoid choking at near sonic speeds, the tunnel bleeds a proportion of its air from the working section, and feeds it back into the mainstream further along. Air may be drawn off via slotted or porous walls; perforated walls are used here.

To minimize structural problems as well as cooling difficulties, operation at near atmospheric pressure is prescribed. The range lies between 0.8 and 1.2 atmospheres; at Mach 1 this gives a stagnation Reynolds Number of 4 by 10^6 in the working section. The main airstream is activated by a two-stage fan driven by a 25,000 horsepower electric motor. Suction plant for removing air from the working section consists of an axial-flow compressor powered by a 13,750 horsepower motor. Each of these motors has the quoted power for a two-hour rating only; continuous powers are 20,000 horsepower and 9900 horsepower, respectively.

Upstream of the working section, the tunnel roof and floor can be adjusted to form a throat; this is variable to give a range of Mach numbers from 1 to 1.6; the upper limit is expected to accommodate ultimate development of the tunnel. All four walls of the working section are perforated: they consist of steel plates in which holes have been punched. Theoretically, no shock-wave reflection should be obtained from these walls. The side plates converge slightly towards the rear of the section and can be adjusted through an angle of one degree about their mean position. The diffuser section also has walls capable of angular variation; by adjustment, a slot of variable size can be obtained between this section and the porous walls. Thus fairly large quantities of air can be extracted through this slot, causing an area of low pressure at the wall. An injector tunnel action is thereby obtained, which increases the speed in the main tunnel. All air extracted re-enters the main circuit through a narrow slot.

Fan diameter is 21 feet and hub diameter is 14 feet. There are two fan stages each consisting of 20 blades; in addition there are two sets of pre-rotation blades, one set upstream of the main compressor and the other between the two stages. A set of straightener

vanes are placed just behind the last fan stage. All the fan blades are fabricated from Honduras mahogany then covered with a fiber glass sheath; their airfoil section is Clark Y while that of the pre-rotation vanes is NACA 6712. It was decided that these sections were quite suitable on the grounds that Mach number at the tips should never exceed 0.7. The rear 20 percent chord of each pre-rotation blade is hinged to act as a flap. With this system it is hoped to get a quick and positive automatic control system based on the working-section Mach number.

Air cooling is effected by water flowing through finned copper tubes located across the tunnel; with these it is expected to keep the air temperature at not more than 25°C even under the most adverse conditions. An air-drying plant is also provided.

Models are sting supported, the sting being mounted on a model cart. Thus by wheeling the cart out of the tunnel, another cart previously prepared may be wheeled into its place. This arrangement will give a minimum of wasted time. The sting on each cart can be rotated through an angle from +22° to -10°. A maximum lift load of 6000 pounds occurring with a side load of 2000 pounds can be accommodated. Strain gages are used to measure all loads. **END**

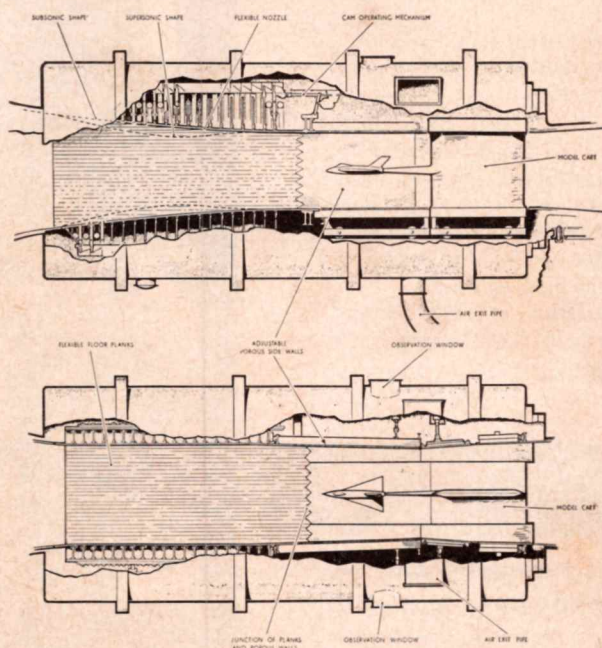


Figure 1—Tunnel working section.

trade literature

You may obtain copies of booklets and pamphlets below by circling the appropriate number on the Reader Reply Card on page 80A.

Mounting Systems. 16 pp illustrated bulletin No. 750 discusses vibration and shock, giving Robinson Aviation, Inc. methods of controlling these factors. MET-L-FLEX all-metal resilient cushions used in Robinson mountings are described. (T-1)

Welding Data Book. 170 pp fifth edition of Eutectic Welding Alloys Corporation pocket data book (TIS 2575) features simplified welding procedures for every base metal, covering 120 welding rods, electrodes and welding compounds. Gives useful "how-to-weld" information for fabrication, maintenance, repair and salvage, overlaying for wear and corrosion resistance and welding of dirty, rusted parts. Special welding applications are covered and data is given on methods of gouging, chamfering and removing of unwanted metal without special equipment. Descriptions of more than 60 Eutectic "Low Temperature Welding Alloys" provide useful alloy selection guide. (T-2)

Microwave Components. 22 pp illus technical catalog covers wide range of standard and custom-engineered microwave components and complex me-

chanical assemblies offered by J-V-M Engineering Co. Can be supplied on pilot run or production quantity basis. (T-3)

Aircraft Accessory Systems. 4 pp illus booklet, issued by Stratos Division of Fairchild Engine and Airplane Corporation, describes their pressurization and air conditioning systems, high and low pressure compressor, valves and controls and a complete group of pneumatic accessories. (T-4)

Rheostats. 4 pp illus bulletin, Section 500 (From TR-10256) covers Columbia Electric Mfg. Co. cast grid type tank rheostats which are available in ampere ratings from 15 to 5000, 1 to 6 volt drop, as specified. (T-5)

Air Control Valves. 4 pp illus quick-reference guide to 17 different lines of air control valves and accessories has been published by Airmatic Valve, Inc. to aid designers in selecting right valve to fit specific application. (T-6)

Alternating Flow of Fluid in Tubes. 7 pp technical publication "Alternating Flow of Fluid in Tubes," Instru-

ment Notes No. 30, now available from Statham Laboratories, Inc. (T-7)

Silicone Rubber. 8 pp illus brochure gives complete specifications on various Silicone compounds available, in addition to providing data on its properties and resistance qualities against a wide variety of conditions. Also covers government specifications which different compounds meet. Raybestos-Manhattan, Inc. (T-8)

Electric Heating Cable. 4 pp illus folder describes new electric heating cable, called Chromalox Silicone Thermwire, which uses heat-resistant characteristics of silicone rubber to permit continued temperatures of 275°F, according to Edwin L. Wiegand Company. (T-9)

Subminiature Switches. 16 pp illus catalog 75a includes completely sealed environment-free subminiature switches and actuators, illuminated push-button assemblies, light force push-button switches and new series of sealed, multi-circuit toggle switch assemblies manufactured by Micro Switch, a Division of Minneapolis-Honeywell Regulator Company. (T-10)

Stop Surface Corrosion FAST and ECONOMICALLY with CEE-BEE's Cleaning and Brightening Method

You can eliminate costly aircraft skin replacement caused by surface corrosion with CEE-BEE's 1-2-3 cleaning and brightening materials. The CEE-BEE method is fast and economical - minimizes man hours required on the job and "out-of-service" time of equipment - provides a longer lasting clean surface, free from corrosion causing oil, smoke and exhaust stains and traffic film. And with CEE-BEE, extra polishing retains hi-lustre longer. Write for free brochure.



CEE-BEE CHEMICAL CO., INC.
9520 East CeeBee Drive
Downey, California

1

CEE-BEE
brightener and
cleaner is applied
with low-pressure
spray or brush.



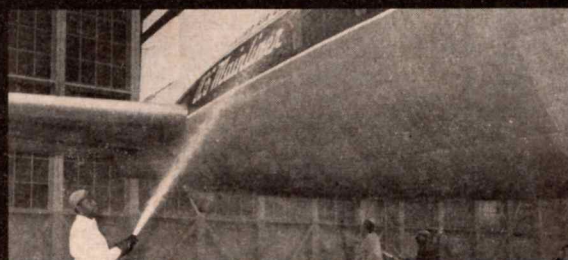
2

CEE-BEE
brightener and
cleaner is brush-
ed to insure cov-
erage, no scrub-
bing necessary.



3

CEE-BEE
brightener and
cleaner is water
rinsed and allow-
ed to air-dry to
bright, corrosion
free finish.



CB 356

For further information circle Reader Reply No. 14

Do-It-Yourself Steel Equipment. 12 pp folder describes methods of assembling lengths of steel angle into an infinite variety of structures. By merely cutting and bolting Dexion Slotted Angle, racks, carts, conveyors, catwalks, tables, gantries, booths, bins and frames can be erected. Cutting marks, slots and holes are provided for quick assembly. Only wrench and Dexion cutter are needed to build and structures can be unbolted, dismantled and built into something else as needs change. Acme Steel Company. (T-11)

Rivet. 4 pp illus bulletin TCL-112 describes new Cherry "700" rivet made by Cherry Rivet Division of the Townsend Company and lists head styles, diameters and lengths available. (T-12)

Beryllium Copper Casting Alloys. 12 pp illus booklet covers available alloys, properties, advantages, casting and processing techniques. The Beryllium Corporation. (T-13)

Pumps. 4 pp illus bulletin No. 403 provides quick but comprehensive view of The New York Air Brake Company, Kinney Division line of small, air-cooled compound high vacuum pumps. Six models are offered, ranging in size from a $\frac{1}{4}$ hp unit which has a displacement of 2.0 cu ft/min to a 3 hp unit having a displacement of 46.0 cu ft/min. (T-14)

Connectors. Illus bulletin 26A gives information on new Series 18 continental connectors available in 20 and 27 contacts from Electronic Sales Division of DeJur Amsco Corporation. (T-15)

Tachometer Generators. Catalog F-4344-3 presents detailed data on new Barber-Colman magnet tachometer generators adapted from their line of type BYLM permanent magnet motors. Three different frame sizes are available with maximum rated outputs of 7000 rpm or 100 volts, whichever occurs first. (T-16)

Intensity Measuring Equipment. 4 pp illus folder describes new NM-40A very low frequency radio interference-field intensity measuring equipment available from Stoddart Aircraft Radio, Inc. Covers frequency range of 30 cps to 15 kcs. (T-17)

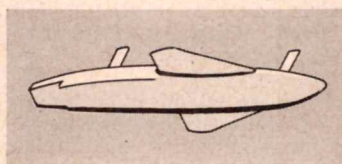
Dynamometer. 4 pp illus pamphlet shows new gram gage for measuring minute pressures, having a range of 0.5 to 5 grams, which George Scherr Company, Inc. has added to its line of dynamometers. (T-18)

Power Transmission Equipment. 12 pp illus technical brochure covers Lovejoy Flexible Coupling Company line of power transmission equipment, including flexible couplings, variable speed pulleys and transmissions, universal joints and motor bases. (T-19)

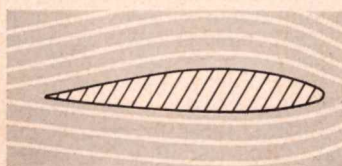
Thermocouple Assemblies. 28 pp illus catalog 1556 covers Conax Corporation's line of thermocouple assemblies and pressure sealing glands, introducing several new products. (T-20)



Yes even ice- and snow-covered areas can be utilized as landing fields for aircraft designed to include the Pantobase landing system. A product of Stroukoff research and development, Pantobase will permit landings and take-offs from snow, ice, sand, water and unimproved terrain, thereby extending the operational capabilities of the aircraft and reducing the need for conventional airports in many remote and previously inaccessible parts of the earth's surface.



Pantobase — When designed into an aircraft the Pantobase system enables the plane to land and take-off from many types of surface without changes of additional landing equipment.



BLC — Boundary layer control as developed by Stroukoff increases the effective lift and delays stalling of the wing, thereby reducing required speeds and distances for take-offs and landings.

Achievement is a tradition at Stroukoff. A leader in the development and design of cargo and transport aircraft, Stroukoff offers challenging opportunities to creative engineers.

Extending the Frontiers  *of Aircraft Performance*

Stroukoff

WEST TRENTON, NEW JERSEY

For further information circle Reader Reply No. 44

Printer Circuit Connectors. Microdot, Inc. offers three new bulletins. No. 44 describes 12 different types of miniature-sized printed circuit receptacles and plus; No. 42 covers compatible micro-miniature coaxial cables; and 43 discusses mating micro-miniature coaxial cable connectors. (T-21)

Temperature Cabinet. Bulletin 61 features Webber Engineering Corporation sub-zero temperature cabinet, Model WE-21-140, with 2 cu ft capacity with front or top opening for testing of electronic components, cold treatment of metals, thermal contraction and expansion fitting. (T-22)

Wire Wound Resistors. 4 pp catalog data bulletin B-5 gives comprehensive data on types, construction, tolerance, dimensions, temperature coefficient and derating of Type BW insulated wire wound resistors manufactured by International Resistance Co. Includes detailed charts and graphs. (T-23)

Chromallizing. 8 pp bulletin No. 5 "Chromallizing Improves Surface Properties of Steel," describes Chromalloy process for increasing heat, wear and corrosion resistance of steel by high temperature diffusion of chromium into the surface. Chromalloy Corporation. (T-24)

Couplings. 4 pp illus bulletin MC-100 shows miniature flexible couplings designed for speeds up to 50,000 rpm made by Thomas Flexible Coupling Company. (T-25)

Nickel Tubing. 20 pp illus catalog 12 features general discussion of nickel and nickel alloy properties as a class and tabulates specific mechanical properties and chemical compositions of 13 analyses of nickel and nickel alloy tubing drawn at Superior Tube Company. (T-26)

Radar Power Supplies. Perkin Engineering Corp. bulletin describes airborne high voltage radar power supplies and more specifically a 6000 volt model. Outlines specifications of the unit which has a d-c output of 6 KV $\pm 5\%$ at 100 microamperes. (T-27)

Transmitting Potentiometers. 4 pp illus bulletin MTT810 gives applications, principles of operation, specifications and ranges of Manning, Maxwell & Moore, Inc. Series 184A transmitting potentiometer pyrometer and Series 184E transmitting potentiometer millivoltmeter. (T-28)

Metallic Abrasives. 18 pp illus catalog No. 556 presents data on Cleveland Metal Abrasive Company line of metallic abrasives and illustrates various types of shot and grit produced by the company in their 20th Century line. Includes SAE specifications and discussion of cleaning and peening methods. (T-29)

Tantalum Capacitors. Bulletin 6.110 discusses Fansteel Metallurgical Corporation's Type STA solid tantalum capacitors which contain no liquid electrolyte. Lists 24 standard ratings from 1 mfd at 35 working volts d-c to 350

mfd at 2 working volts. Also contains performance characteristics curves. (T-30)

Switches. 8 pp illus booklet describes design, manufacture and characteristics of Mycalex Electronics Corporation Model TM 55 series commutation switches for telemetering and similar applications. (T-31)

Thermocouple Accessories. 4 pp illus bulletin No. 1610-A describes adapters, resistors, terminals and firewall, bayonet and quick-disconnect connectors available from Revere Corporation of America. (T-32)

Plica Tubing. 4 pp bulletin 61 presents data on The Flexaust Company's Plica, hand bendable tubing. Major applications to date have been as electrical conduit, air lines, insulating and protective covers. (T-33)

Fasteners. Pocket-size physical properties card lists physical properties of fasteners manufactured by Cleveland Cap Screw Company. Printed on Vinyl plastic, it gives such physical properties as steel analysis, head marking, tensile strength, Brinell and Rockwell hardness on screws up to $2\frac{1}{2}$ in. in diameter. (T-34)

Centrifugal Blowers. Condensed 4 pp catalog, F 4344-3, describes Barber-Colman permanent magnet centrifugal blowers, motors, gearheads and generators. Blower voltages range from 6 to 115 v d-c. (T-35)

Valve Stem Packings. 4 pp illus bulletin describes manner in which they are made, illustrates shapes most commonly used and lists size limitations. Also provides recommendation chart for standard items when used against various fluids and gases. Raybestos-Manhattan, Inc. (T-36)

Plastic Products. 6 pp illus bulletin covers Raybestos-Manhattan plastic products made of Teflon and Raylon, listing chemical, electrical and mechanical properties of these resins. Gives specifications on sizes in which sheets, tape, molded and extruded rods and tubes are available. (T-37)

Tube Selection Chart. Lists General Electric's 5-star tubes for critical applications. Chart (ETD-1276) classifies the 34 tubes, applicable military specifications, heater voltages and currents, and gives average characteristics. (T-38)

Plastic Films. 4 pp brochure explains use of Reynolon PVA/4-6 Series Plyvinyl Alcohol plastic films in forming reinforced plastics. Includes technical data on properties and characteristics of films, as well as Reynolon "Release", a new mold release parting solution. Reynolds Metal Co. (T-39)

Vibration and Shock Mounts. Illustrated 25 pp booklet explains Robinson Aviation Inc. concept of vibration and shock control for airborne electronic equipment and describes several of their engineered mounting systems. (T-40)

calendar

Aug. 21-24—Western ELECTRONICS Show and Convention, sponsored by IRE and West Coast Electronic Manufacturers Association, Pan-Pacific Auditorium and Ambassador Hotel, Los Angeles, California.

Aug. 22-24—Bendix Scintilla International IGNITION Conference, Sydney, New York.

Sept. 1-3—1956 National AIRCRAFT SHOW, Will Rogers Field, Oklahoma City, Oklahoma.

Sept. 3-9—Society of BRITISH AIRCRAFT CONSTRUCTION Exhibition and Flying Display, Farnborough, England.

Sept. 10-14—Colloquium on TRANSPORT PHENOMENA IN METALS, International Union of Pure and Applied Physics, Ottawa, Canada.

Sept. 10-14—International Conference on FATIGUE OF METALS, London, England.

Sept. 12-22—INTERNATIONAL AIR RACES, U. S., England, South Africa. Starting from Floyd Bennett Field, Brooklyn, New York.

Sept. 17-22—International ASTRONAUTICAL Federation, 7th Annual Congress, Rome, Italy.

Sept. 17-21—Instrument Society of America, 11th Annual INSTRUMENT-AUTOMATION Conference and Exhibit (International), New York City.

Sept. 18-19—Symposium on Technology of MOLYBDENUM and MOLYBDENUM BASE ALLOYS, Sponsored by Engineering Society of Detroit, Rackham Memorial Building, Detroit, Michigan (Further information from J. J. Harwood, Office of Naval Research, Washington, D. C.)

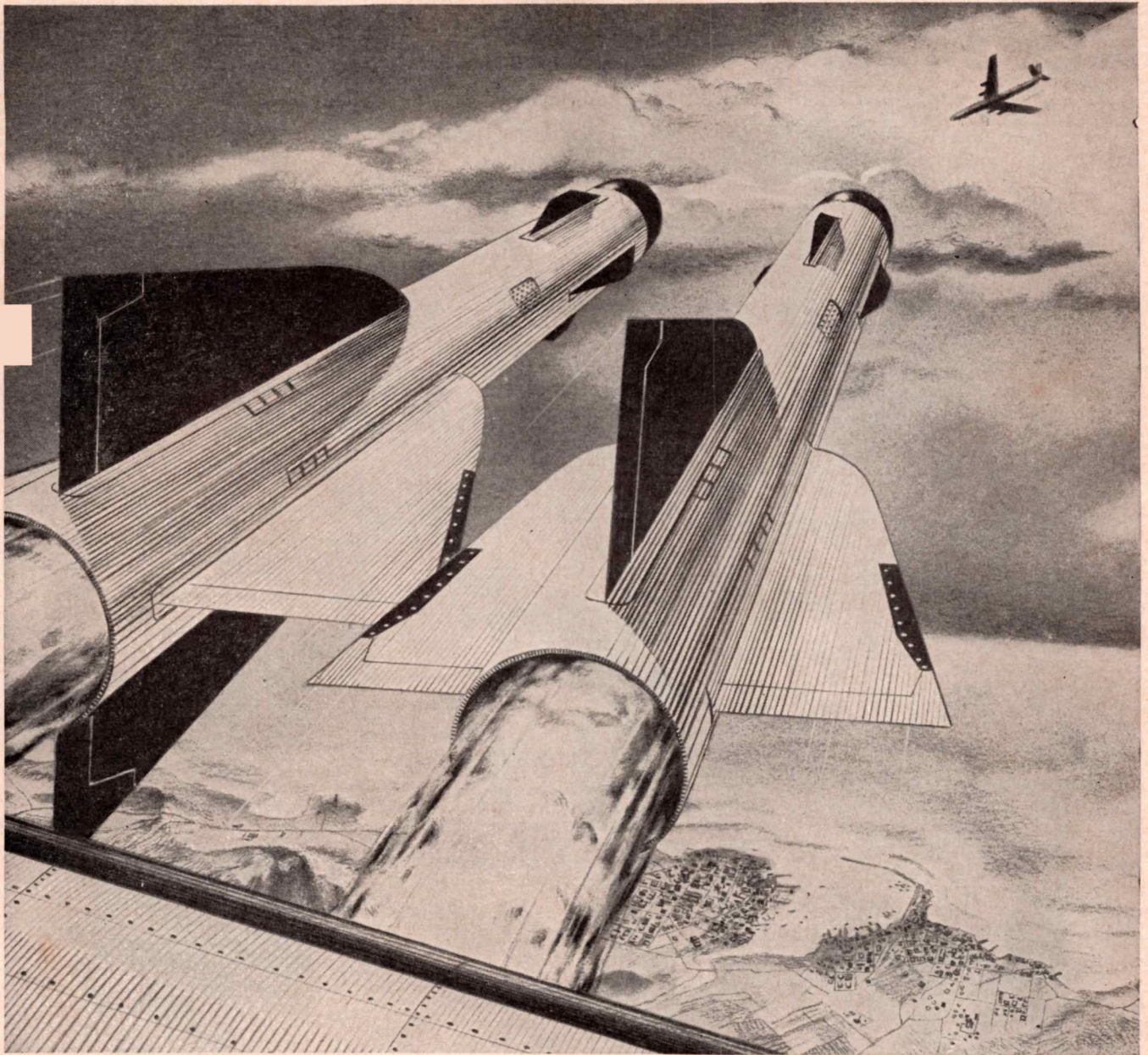
Sept. 25-29—International Association of Aircraft Constructors, JET TRANSPORT Conference, The Hague, Netherlands.

Oct. 1-3—12th Annual National ELECTRONIC CONFERENCE, Hotel Sherman, Chicago, Illinois.

Oct. 2-6—National Aeronautics Meeting, Aircraft Production Forum and Aircraft Engineering Display, Sponsored by Society of AUTOMOTIVE ENGINEERS, Hotel Statler, Los Angeles, California.

Oct. 8-9—Second National Symposium on AERONAUTICAL COMMUNICATIONS, Sponsored by IRE Professional Group on Communications Systems, Hotel Utica, Utica, New York.

Oct. 25-26—Aircraft Electrical Society Annual Display of AIRCRAFT ELECTRICAL EQUIPMENT, Pan-Pacific Auditorium, Los Angeles, California.



Solar skills help produce guided missiles in quantity



INFORMATION BOOKLET

New brochure on Solar missile production capabilities—write for a copy today.

GUIDED MISSILES REQUIRE imaginative engineering and precision fabrication with unending emphasis on quality. Solar has stressed these attributes for decades in designing and building aircraft components of tough alloys for use under stringent service conditions. In addition, Solar's direct activity in missile programs extends from research and development work through to volume manufacture of components—such as current fabrication of fuselages for the air-to-air Hughes Falcon. For more information on Solar's missile production capabilities, write Dept. C-53, Solar Aircraft Company, San Diego 12, Calif.

For further information circle Reader Reply No. 42

SOLAR
AIRCRAFT COMPANY



SAN DIEGO DES MOINES

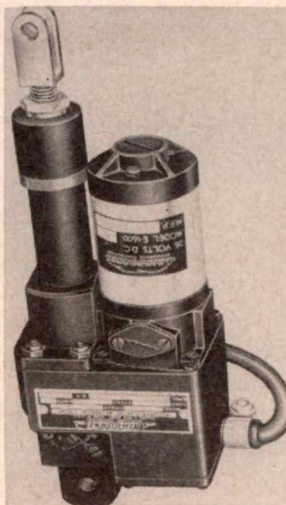
Designers, developers and manufacturers of gas turbines—
aircraft and missile components—bellows—controls—high
temperature coatings—metal alloy products

new equipment

For further information use Reader Reply Card on Page 80A.

Silicone Rubber Insulated Wire. Continental Wire Corporation says their new silicone rubber insulated wire, designed for high temperature resistance (up to 500°F), is especially suitable for small conductors in many electronic applications. Continental's products include asbestos, varnished cambric, nylon, glass, Teflon, Kel-F, polyvinyl and polyethylene insulations. (E-1)

Self-Correcting Automatic Navigator. Lear, Incorporated, has applied for broad patents on a small "black box" having man-like powers of deliberative judgment, and the first use will be for aircraft navigation. It is said the device follows precise rules of logic in reasoning whether to accept, reject or demand confirmation of data fed into it. System, called the Lear SCAN, will enable an aircraft to fly straight to its target over enemy territory despite any attempts at electronic jamming, and without disclosing its presence by emitting any radiation. (E-2)

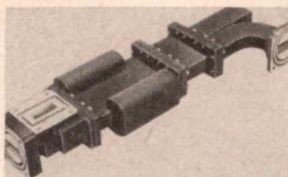


Linear Actuators. Airborne Accessories Corporation's expanded line of electro-mechanical aircraft equipment includes R-5160 series 26VDC load sensitive linear actuators. Available in strokes to 7¼ in. unit features adjustable load sensitive switches, magnetic braking, radio noise filter, optional thermal protection and anti-rotation device. (E-3)

Insert Liner. A Beryllium copper spring finger liner material is now available from International Electronic Research Corp. in sizes to fit all miniature JAN type shields. Manufacturer says liner affords substantial bulb temperature reductions of up to 30% as compared to the regular JAN

shield when tested on a heat slug as described in MIL-S-9372C. (E-4)

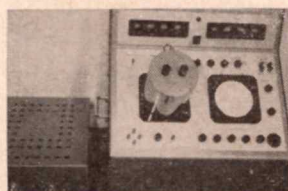
Silver Brazing Alloy. New form of silver brazing alloy—expanded and rolled strip—has been developed by Handy & Harman, who say principal advantage of the expanded strip is weight reduction, which is of particular importance in assemblies for aviation service, such as honeycomb structures, propeller blades and other large components customarily assembled by brazing. (E-5)



Duplexer. New X-band ferrite phase differential duplexer, designed and manufactured by Airtron, Inc., incorporates in a single device both duplexer and load isolation action which assures optimum magnetron spectrum and power output with consequent good AFC performance, according to the manufacturer. (E-6)

Silicone Compound. A silicone rubber cloth coating compound for ducting which can carry air at temperature as high as 700°F and remain flexible at 120° below has been added to standard product list of Silicone Products Department, General Electric Company. Designated SE-701, this compound is for such applications as hot air ducts, jet engine starter hose, flexible connectors for metal ducting and aircraft fire wall seals. (E-7)

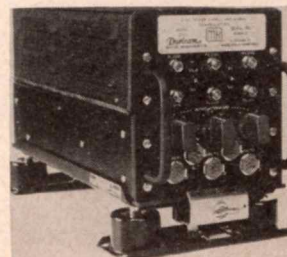
O-Ring Compound. New 90 durometer synthetic material has been developed by the Parker Rubber Research & Development Laboratory for molded seals in services up to 300°F with MIL-L-7870A grease for lubricating aircraft instruments and MIL-L-6083 oil for preservative purposes in hydraulic equipment. New material, designated Parker O-ring compound 49-091, is also recommended by the company for use with MIL-L-7808A and MIL-L-5606 oil up to 250°F. (E-8)



Dampometer. Olsson-built dampometer, a Swedish electronic apparatus

for damping the aerodynamics, structures, acoustics, metallurgy and electronics, has been introduced on the American market by Oltronix Company. In the dampometer, a damped sinusoidal voltage is represented by a rotating vector on the screen of a cathode ray tube. Rate of decrease in the vector's length is an accurate measurement of the damping. Results show on two electronic counters simultaneously with the test. (E-9)

Hose. To be used for fuel, lubricant and hydraulic lines in jet and conventionally powered aircraft as well as in rockets and guided missiles, hose is said to have the widest useful temperature range of any flexible material, remaining strong and flexible at temperatures as low as -100°F and as high as +450°F. B. F. Goodrich Industrial Products Company says hose weighs about half as much as conventional aircraft hose and consists of a seamless tube reinforced with braids of stainless steel wire for strength and resistance to corrosion. (E-10)



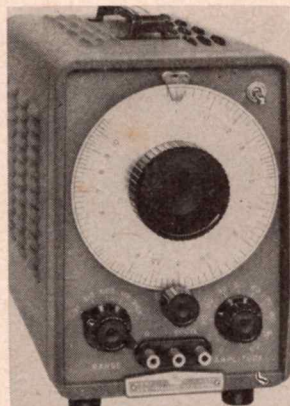
Power Supply - Demodulator Unit. Model DV-1 has been developed by Doelcam, a Division of Minneapolis-Honeywell, for use with gyros in flight test applications where 115-volt 400-cycle single-phase primary power is available. Unit properly energizes the motor and pickoff of each gyro and converts the a-c output signal of each pickoff to d-c for use with oscillograph galvanometers. (E-11)

Autoclave. Narmco Manufacturing Company recently completed installation of an autoclave, which provides the necessary pressures and temperatures to cure adhesives and resins to structurally bond parts together, (such as wing tips, rudders, elevons, landing wheel doors). Oven, which has interior diameter of 8 ft and is 40 ft long, will handle the largest bonded structures now being designed into aircraft and missiles. (E-12)

Hot-Melt Compound. Machining of stainless steel honeycomb structures has now become possible through a newly developed hot-melt compound

developed at Furane Plastics Incorporated. With Hot Melt H-883-A, and its low linear shrinkage, the cells of the stainless steel honeycomb are maintained during the machining operation, according to the manufacturer.

(E-14)



Oscillator. Multi-purpose low frequency oscillator, Model 202C, provides pure waveforms for subsonic, audio and supersonic measurements according to the Hewlett-Packard Company. Offers high output power of 160 milliwatts delivered from a transformer-coupled balanced matched source and covers frequencies 1 cps to 100 kc in five ranges.

(E-13)

Propeller Synchronizer Test Machine. Introduced by Greer Hydraulics, Inc., in collaboration with the Hamilton Standard Division of United Aircraft, unit provides for rapid and accurate "after-overhaul" and "pre-flight" checks of 2- and 4-engine synchronizers and their components under precise conditions encountered in actual flight.

(E-15)

Epoxy Laminate. Added to a line of glass-base sheet laminates bonded with an epoxy resin is a new epoxy laminate, available from National Vulcanized Fibre Co. Identified as Grade G-10-865, it comes in sheet sizes of 39 x 47 in. with thicknesses from 1/32 to 1/2 in.

((E-16)

Packaging. Robinson Aviation, Incorporated claims their precision packaging for delicate equipment provides protection against shock and vibration with newly developed all metal mounts for transit cases, which are specially designed to fit any type of reusable container in wide use. By using MET-L-FLEX stainless steel resilient elements, resistance to extreme temperatures, water, dirt, oil, insects and fungus is assured throughout long storage periods or the most destructive transport.

(E-17)

Couplings. Eastern Aircraft Products Corporation says their complete line of breakaway couplings feature positive ball lock which prevents the connection from shaking loose under severe vibration. Units are available self-sealing both halves, self-sealing one half or non-self sealing.

(E-18)

Guided Missile Cable. Especially suited for use in guided missile motors and

in electronic controls, cable is available from the Federal Telephone and Radio Company. Designated Type SP-132, it is a four conductor (two twisted pairs) type with tinned copper conductor, tinned copper braid, polyethylene insulation and polyvinylchloride jacket. Has a maximum OD of .275.

(E-19)

Spline Nut. New self-locking spline type nut has been developed by the Elastic Stop Nut Corporation of America to provide tighter grip and smoother installation in aluminum and magnesium alloys. Designed to be used as self-wrenching fasteners for aircraft and industrial applications, Type ND2398 spline nuts serve as blind mounting fasteners for spots where it is desirable to have an attached nut for ease of maintenance.

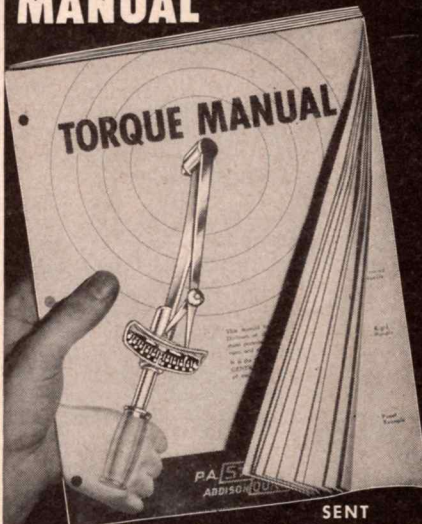
(E-20)

Plane Radio Antenna. New type radio antenna for airplanes, developed by Boeing Airplane Company engineers and fitted on the tip of the Boeing 707 jet transport prototype's vertical tail fin, is undergoing air tests. The "probe" antenna will be for long-range high-frequency radio communications. In appearance like a spear pointing forward from the airplane's fin-tip, antenna provides "vertical polarization" of the high frequency radio waves, which allows them to follow the earth's curvature as well as bounce off the ionized layers in the earth's atmosphere. For communications over ranges too long for use of VHF and UHF radio.

(E-21)

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abstracts

K. Leist and W. Dettmering, **TURBINENSCHAUFELN AUS KUNSTSTOFF FÜR KALTLUFTUNTERSUCHUNGEN**, DVL Bericht Nr. 4, December 1955. West German Press, (22a) OPLADEN/RHLD, West Germany, price: 12.30 DM (In German)

The use of plastics of various types for flow machine experiments is recommended because of the ease with which they can be worked and their high shearing length at low temperatures. Since to a great extent flow experiments are conducted with cold air, the use of such materials represents an easy way to produce various turbine models, even quite complicated types, quickly.

The report describes the methods of producing entire circles of blades of Plexiglas and various test blades of cast resins, also the limit of use of such materials as determined in experiments.

H. Söhngen, **STROMUNG VOR EINEM ÜBERSCHALL-LAUFRAD**, DVL Bericht Nr. 11, December 1955. West German Press, (22a) OPLADEN/RHLD, West Germany, price: 7.60 DM. (In German)

The subject of investigation is the flow in front of an ultrasonic axial compressor, which consists of a single turbine wheel that is subject to a flow at ultrasonic speed. For a simple model, one must take into consideration the reflections on the intake from the disturbances originating from the wheel and the modifications which are therefore necessary in the flow around the blades.

C. Dewey Havill and L. Stewart Rolls, **A SONIC-FLOW ORIFICE PROBE FOR THE IN-FLIGHT MEASUREMENT OF TEMPERATURE PROFILES OF A JET ENGINE EXHAUST WITH AFTERBURNING**, NACA TN 3714, May 1956.

A temperature-measuring system using two sonic-flow orifices in series is described. This system was adapted to measure the exhaust gas temperature of an afterburning jet engine and was mounted in a swinging pitot-static probe. The sonic-flow orifice system had only a small variation in temperature at the thermocouple and temperature change was measured as a change in pressure. Measurement of exhaust temperature of 3200° R was obtained during afterburner operation in flight.

Donald E. Swarts and Milton Orchin, **VAPOR-PHASE OXIDATION AND SPONTANEOUS IGNITION—CORRELATION AND EFFECT OF VARIABLES**, NACA TN 3579, April 1956.

The spontaneous ignition temperatures of eight structurally different hydrocarbons were determined and correlated with the behavior of the same hydrocarbons toward vapor-phase oxidation. Since good correlation of the two phenomena was obtained, it is likely that similar oxidative mechanisms are operative in both.

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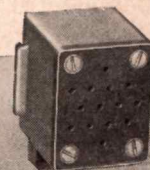


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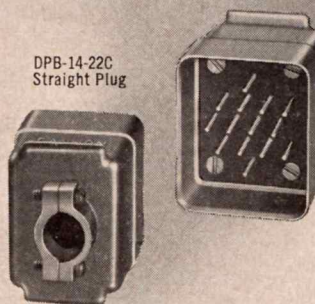
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A QUESTION OF STATUS

ALL OF A SUDDEN engineers are heroes. Industry is wooing them. Newspapers and magazines are extolling their virtues and calling them the country's first line of defense. So vital are they, that some experts say they are America's secret weapon.

Industry's courtship is being experienced even by engineering-college juniors. In fact, the need for engineers is so great that it is being felt in secondary schools where working engineers are called to lecture on a part-time basis in order to encourage more students to enter science.

With a situation such as this, an observer would expect that engineers would be a happy lot, content in their jobs and highly appreciated by their employers. In some cases this is true, but in many others the engineers are becoming increasingly frustrated. The reason, quite bluntly given, is lack of professional recognition. By many managements, engineers are treated not as professional men with creative ideas to contribute, but rather as IBM cards, 100 or so of which are needed to complete an engineering project.

As a result, engineer employees show feelings towards their employers only slightly more favorable than those of production workers and factory labor. According to the Industrial Relations Center of the University of Chicago, engineers' attitudes appear to be about the same as those of routine office employees; the men are definitely less satisfied than skilled workers, foremen and salesmen. "In practically every professional group that had been surveyed, with the exception of relatively few cases, there was strong evidence of discontent and generalized dissatisfaction."

We all know that there are many ways to make a living—some undoubtedly easier than engineering and more remunerative. Yet, the engineer chooses his profession and his specialty because in large part he wishes to contribute to the field and obtain recognition for his proven abilities. Working in a setting in which individual recognition is difficult to secure is not likely to satisfy the personal needs of the professional. More than this, working in a setting where aggressive social effort rather than ability may be needed for status could easily depress the morale of any competent technical worker. As one engineer, an old-timer, said to the surveyors, "I can tell you why the engineers around here don't have high morale. This company takes pride in its engineering and technological achievements, if you can believe the ads. But I also know that the

executive vice president has been heard to say on many occasions, 'You can hire technical brains a dime a dozen.'"

Although the findings of the Industrial Relations Center indicate chronic dissatisfaction among a large number of professional and technical employees, there were two groups in which these feeling were not present. Each of these high-morale groups comprised successful research teams, each having developed promising new products for their companies. Contrariwise, the most demoralized group surveyed was one that had failed to gain acceptance for its ideas. Whether the recognition of the high-morale groups begot further successes is not known, but one can easily examine what his own attitude would be.

How much even slight recognition means was shown by a letter sent in by one engineer, who said in part: "Little courtesies, like Christmas greetings or congratulations on new babies, are never extended by management. Management does not mingle with workers at parties or elsewhere except when absolutely necessary."

Engineering colleges tell their students that they are entering a profession. Legally, engineering is recognized as a profession. The public accept this fact as well as the recruiters for engineering talent. It is not strange, then, that engineers should think of themselves as professionals. If they contribute as such, they should be recognized as such. Some companies grant this, but not many. (We would be delighted to learn from our readers about those companies that do.)

Today, the aircraft industry has the chance to do what no other industry has done—put its engineering employees on a professional basis. Aside from the abundant credit that would be given to the industry for its foresightedness, it would be assured of high morale among its engineers and maximum contributions from them. Looking further into the future, industry would find its task of interesting young students in engineering vastly simplified. For any aggressive company that would take the step today, it would probably find, once the word got out, that it had decreased its turnover rate among technical employees to a point close to zero, and had drastically decreased its need for new engineering talent. Surely, such an opportunity is worth studying.

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